The Impact of Logging Damage on Tropical Rainforests, their Recovery and Regeneration

an Annotated Bibliography

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Cover Illustrations

Top left: Skidding a log along a skid trail, viewed from a larger cleared area

Top right: Larger gaps, which regenerate poorly, include the main logging roads.

Bottom left: Seedlings in elephant dung, including *Desplatsia* spp. (smaller) and *Ricinodendron.* Elephants in Bia South are disturbed by logging, yet help with the regeneration of some plant species.

Bottom right: Regeneration in loading bays is usually poor except around the edges. Here it dominated by the alien invasive weed *Chromolaena odorata.* A sample transect across the area is being recorded by the field team.

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An Annotated Bibliography

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BACKGROUND

This annotated bibliography is an output from a DFID/FRP project (R6716 – *Impact of harvesting on forest mortality and regeneration in the high forest zones of Ghana).* The aim of the project as a whole was to improve our knowledge of the negative impacts of logging in tropical rainforests, and to recommend improvements in the logging system. The focus of the bibliography therefore has a Ghanaian/West African slant, although papers from across the tropics are included as well as some relevant papers from temperate regions.

At its core, the bibliography summarises available knowledge on logging damage and recovery, forest regeneration, and the allometry, growth, dispersal, reproduction and death of trees related to logging disturbance. It also documents the logging system in Ghana. Some key zoological references are included, mainly thanks to the efforts of A. G. Johns and L. Darcy, which cover the impact of logging on tropical forest animal biodiversity, the role of animals as dispersers and pollinators, and as bio-indicators of forest condition. Social and economic impacts of logging are not treated, although they are of direct relevance to tropical forest management and conservation.

This is a broad set of subject areas, each of which is extensive on its own, with a disproportionate amount of unpublished ‘grey’ literature circulating in internal reports and bulletins. We have tried to obtain some of the more relevant documents in the time available, but there must be very many more.

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INTRODUCTION

Data are presented in many ways in the literature, which can make the conclusions of different studies difficult to compare. It is hard to be certain of the relevance of two studies to each other when the species list is different, increasingly so when they are from different continents, and compounded by the use of different methods of evaluation and categorisation by researchers. Some topics, like the amount of damage to be expected when trees of various sizes are felled, travel better than others, such as phenology. Nevertheless, some consensus on the impacts of logging exists. Integrated reviews of many topics covered here, as they might be applied to forest management, can be found in a number of summary papers and books (e.g. Baur, 1968; Chazdon, 2003; Dawkins, 1958; De Graaf, 1986; Ghazoul & Shiel, 2010; Gomez-Pompa *et al.*, 1991; Lamb, 2011; Meijaard *et al.*, 2005; Mergen & Vincent, 1987; Putz & Viana, 1996; Ter Steege, 1996).

Logging Damage

When tropical forest is logged under a typical selection system, logging roads leading into the heart of the forest are built off the public road network. Major forest roads lead to minor forest roads, eventually reaching a loading bay. Logs are usually dragged ('skidded') from their stump to the loading bays, leaving skid trails. Loading bays and roads are completely cleared of vegetation, and the soil often becomes very degraded through compaction, and they show poor regeneration. However, because they are reused each cycle, and one or two will suffice for a large logging compartment, their impact is perhaps more minimal than that of the skid trails and felled tree gaps (Hawthorne, 2003). Skid trails are therefore the focus of 'regeneratable' damage (FAO, 1977, 1980, 1983; Hawthorne, 1993; Heinrich, 1978) and the regeneration of skid trails in particular is covered e.g. by Bonnell *et al.*, 2011; Dickinson *et al.*, 2000; Guariguata & Dupuy, 1997; Pancel, 1993.

Whereas felling injures neighbouring trees, especially crowns, skidding tends to increase mortality in the very short term (Bertault & Sist, 1995, 1997; Nicholson, 1958, 1979; Pinard & Putz, 1996; Sist et al, 1998). In conventionally logged forest in Indonesia, Sist *et al.* (2003) found that skidding was responsible for twice the number of tree deaths as felling. Because skid trails can be re-used, and felled tree gaps can overlap, Panfil & Gullison (1998) found damage increased in a quadratic function of harvesting intensity.

A great many papers assess logging damage in particular forests: in Indonesia (e.g. Cannon *et al.*, 1998; Slik *et al.*, 2002; Sist & Nguyen-The, 2002; Kartawinata *et al.*, 2001); in Central Guyana (e.g. ter Steege *et al.*, 2002); in the Western Ghats (e.g. Pelissier *et al.*, 1998); in Uganda (e.g. Chapman & Chapman, 1997); in the Brazilian Amazon (e.g. Silva *et al.*, 1995); in French Guyana (e.g. Molino & Sabatier, 2001); in Sabah Malaysia (e.g. Pinard & Putz, 1996; Pinard *et al.*, 2000). Some studies report on damage by tree (e.g. Hernandez-Diaz & Delgado-Pacheco, 1995 in Mexico), or discuss forest areas only (Hawthorne, 2003, in Ghana).

Other studies use mathematical models

to predict the amount of damage associated with the extraction of different amounts of timber by various logging methods, e.g. Boscolo and Vincent, 2000; Buongiorno and Michie, 1980; Crome *et al.*, 1992; Johns, 1992; Macpherson *et al.*, 2010. Verissimo *et al.* (1995) estimated that 30 trees >10cm DBH were severely damaged per tree felled in Brazil, whereas Bird (1988) observed averages of 0.5, 17 and 50 trees >10cm DBH in Belize. One important source of variation is the size of the trees being felled, and another is slope, where skid trails are obliged to follow contours rather than the most direct route (Hawthorne, 2003).

More recently there have been developments in remote sensing of forest degradation and deforestation, allowing canopy monitoring after logging over much larger areas (Asner *et al.*, 2004: Asner *et al.*, 2010). Asner *et al.* (2004) found that loading bays had the largest forest gap fractions, but contributed little to landscape level gap dynamics. Tree falls were spatially the most extensive form of canopy damage, but the canopy gap fractions resulting from them were small. Regional-scale analysis in Amazonia showed that half of the canopy gaps had closed one year after logging.

Logging disturbance can be important for the regeneration of certain species, such as *Swietenia macrophylla* and *Cedrela* spp. in the Americas, *Entandrophragma* spp. in Africa, and *Shorea leprosula* in Asia (Fredericksen and Putz, 2003). In other circumstances, logging disturbance may create an environment that is unfavourable, particularly if combined with heavy harvest pressure (Chazdon, 2003), as is the case with many highly valuable species in the Amazon region (Schulze *et al.*, 2008).

There are various modes of logging, but selective logging or Reduced Impact Logging (‘RIL’) techniques (e.g. Dykstra, 2002) are now well established. Some barriers to full implementation exist (e.g. Pokomy *et al.*, 2005; Putz *et al.*, 2001). There is evidence that RIL reduces the damage associated with logging: Sist *et al.* (1998) found that RIL reduced damage overall by 50% compared with conventional logging at a harvest intensity of 8 stems/ha, but at higher logging intensities improvements were less marked. Pinard & Putz (1996) found that conventional and RIL areas contained biomass equivalent to 44% and 67%, respectively, of pre-logging levels, one year after logging. Holdsworth & Uhl (1997) found that RIL reduced the risk of fire subsequent to logging; Macpherson *et al.* (2010) found that RIL reduced forest recovery time in their matrix model compared with conventional logging.

An important aspect of RIL is the pre-felling cutting of lianas. Lianas have been shown to exacerbate the effects of logging, and also have a negative effect on growth and yield, so have been increasingly studied in this context (Appanah & Putz, 1984; Cedergren, 1996; Fox, 1968; Gerwing & Uhl, 2001; Liew, 1973; Neil, 1984; Parren & Bongers, 2001; Pinard & Putz, 1994; Putz, 1984; Putz *et al.*, 1984; Schnitzer *et al.*, 2004).

Appanah & Putz (1984) found that climber cutting reduced the number of trees pulled down with logged trees by half in forest with high climber density (376/ha >2cm DBH); although in a different context Cedergen (1996) found that climber cutting had no effect, and Parren & Bongers (2001) also found that climber-cutting did not significantly decrease tree mortality or damage. Putz (1984) found that 90% of cut adult lianas survive when they are dragged into felled gaps, and this strong regeneration of climbers can inhibit the recolonisation of gaps by tree species (Neil, 1984). Pre-cutting of lianas in Brazilian forests was shown to significantly reduce liana proliferation in logging gaps after 6 years (Gerwing & Uhl, 2002), and Schnitzer *et al.*, (2004) concluded that liana cutting was an effective method to reduce the abundance of lianas in logging gaps, minimising the detrimental effect on regenerating trees.

Yeom (1984) reported that global timber production from natural tropical forests low (5-35m^3 of merchantable wood per hectare). However, at least half of the remaining stems are beyond recovery during logging (Barbier *et al.,* 1992). This coupled with extremely arduous working conditions in the forest make harvesting operations expensive (FAO, 1993). A solution to the high cost of exploitation per unit area is to increase yield by minimising logging waste and encouraging increased exploitation and utilisation of less used species (LUS) (Yeom, 1984; Wehiong, 1990).

Although almost all work has concentrated on commercial logging, Lawes *et al.* (2007) noted that the impact of commercial logging 100 years ago at a site in South Africa can still be seen today because the understorey species that regenerated in the logging gaps have subsequently been the focus of local subsistence harvesting of small DBH poles from the forest. There is also a literature on the impact of salvage logging, when timber is recovered from forests following natural disturbances such as hurricanes. Lindenmayer & Noss (2006) stated that impacts can be negative, positive or neutral, additional to or different from the effects of traditional logging, and depend on initial circumstances. See also Peterson & Leach, 2008; Phillips *et al.*, 2006.

The species richness of animal populations (ants, birds, and Lepidoptera) following a) logging and b) conversion of forest to agricultural land is reviewed by Dunn (2004), using data from 34 studies. Meijaard *et al.* (2005) review ecological and life-history information for a range of Bornean wildlife species, aimed at identifying what makes these species sensitive to timber harvesting practices and associated impacts. Other reviews addressing the impact of logging on fauna include Johns, 1997 and Putz *et al.*, 2000.

Literature addressing the impact of timber harvesting methods and operations on animal taxa is biased towards birds and primates. For birds (e.g. Abbott & van Heurck, 1985; Allport *et al.*, 1989; Ayres & Johns 1987; Cleary *et al.*, 2008; Cockle *et al.*, 2010; Dale & Slemby, 2005; Du Plessis 1995; Edwards *et al.*, 2009; Eyre *et al.*, 2009; Holbech, 2005; Johns, 1986; Johns, 1991a; Kalina, 1988; Kofron & Chapman, 1995; Mason, 1996; Massimino *et al.*, 2008; Obua, 1992; Peh *et al.*, 2005; Pinto Henriques *et al.*, 2008; Thiollay, 1992; Whitman *et al.*, 1996; Wunderle *et al.*, 2006; Zurita & Zuleta, 2009), authors have variously reported: significant decreases in bird species richness and diversity; only slight differences in species diversity; and similarity in bird richness, but with important changes in species abundance and composition after logging.

Primate responses to logging (Asibey, 1978; Bonnell *et al.*, 2011; Branch, 1983; Chapman *et al.*, 2000; Fairgrieve, 1995; Gillespie *et al.*, 2003; Johns, 1991b; Johns, 1983; Lehman, 2003; Oates, 1996; Olupot *et al.*, 1994; Petter & Peyrièras, 1974; Plumpetre, 2006; White, 1992;) are also variable. Some primate species are highly dependent on undisturbed forest (specialists like *Hylobates* spp.; *Cercophitecus* spp.; *Chiropotes* spp.), while others prefer disturbed habitats and will be more likely to survive in disrupted areas (generalists like *Macaca* spp.; *Colobus* spp.; *Cebus* spp.) (Azevedo-Ramos, 2005). After logging, the intensity of hunting increases primarily because of easier access to remote forests by new roads and of the greater human presence in the area, and this impact is an important component of the impact of logging (Bennett & Robinson 2000; Putz *et al.* 2000).

There has been some interest in the use of animal groups as bioindicators for forest condition (Aguilar-Amuchastegui & Henebry, 2007; Azevedo-Ramos, 2005), but due to the relative expense of surveying animal groups, the lack of consistent results between studies and paucity of evidence linking particular animal groups to others, the results are not particularly encouraging.

Recovery after Logging

Many studies focus on structural measures of logged forest recovery, such as basal area, aboveground biomass, tree height, or stem density (e.g. Abdulhadi, 1981; Bertault & Sist, 1995; Bird, 1998; Bonnell *et al.*, 2011; Cannon *et al.*, 1994; Chandrashekara & Sreejith, 2006; Chazdon *et al.*, 2007; Elias, 1995; Gerwing, 2002; Johns, 1988; Jonkers, 1987; Ola-Adams, 1987, Silva *et al.*, 1995; Tang, 1976; Taylor *et al.*, 1996; Van der Hout, 1996; Wong, 1998). Other studies have examined changes in canopy structure, the frequency and size of canopy gaps, and light availability during forest recovery (e.g. Denslow & Guzman, 2000; Nicotra *et al.*, 1999; Yavitt *et al.* 1995).

Changes in species composition occur independently of changes in structural variables, and show far more long-lasting legacies of disturbance (Chazdon, 2003). Aboveground biomass re-accumulation can occur on a scale of decades, while species composition recovery can take centuries (Guariguata & Ostertag, 2001). Studies that focus on changes in species composition, density, richness, evenness or diversity after logging include Aide *et al.*, 2000; Bergstedt *et al.*, 2008; Castro-Luna *et al.*, 2011; Dupuy & Chazdon, 2008; Gutierrez-Granados *et al.*, 2011; Hall *et al.*, 2003; Hawthorne, 1993; Kasenene & Murphy, 1991; and Liebsch *et al.*, 2009; Makana & Thomas, 2006.

In addition, Chua *et al.* (1998) found that although alpha species diversity and species richness had increased following logging in Malaysia, the concentration of globally restricted species (the ‘bioquality’) had decreased, so that logged areas were relatively more dominated by globally widespread species. However, King & Chapman (1983) found that a logged forest area with 90% of its canopy removed had recovered all species after 25 years. Although much of the literature focus on the recovery of timber tree species, recovery has been examined for herbs, lianas, and non-vascular epiphytes, e.g.

by Turner *et al.*,1996; Romero, 1999; Costa & Magnusson, 2002; Schnitzer & Bongers, 2002; Parrotta, 1995.

The impact of logging on soil nutrients and cycling is another important area of research (Gillman *et al.*, 1985; Nussbaum *et al.*, 1995; Silver *et al.* 1996). Disturbance that impacts soils as well as above ground vegetation, such as the use of bulldozers and skidders during logging operations, can significantly slow down the rate of forest structural recovery and can have long-lasting effects on species composition. The recovery of soil fertility is closely linked with the recovery of aboveground biomass (Chazdon, 2003).

Forest recovery can also be measured in terms of the abundance and richness of species used for non-timber products, e.g. Adnan & Holscher (2011) found that 10 important medicinal species were most abundant in old-growth forests in NW Pakistan. The Brazil nut (*Bertholletia excelsum*), appears to regenerate best in large gaps and other disturbed areas (Myers *et al.* 2000). Dirzo & Miranda (1991) suggested that the recovery of species interactions is another metric that should be used more widely. Several studies have examined recovery of particular species, with a focus on tree population structure, genetic diversity, and overall changes in abundance (e.g. Andre *et al.*, 2006; Degen *et al.*, 2006; Jennings *et al.*, 2001; Wernsdorfer *et al.* 2011).

Regeneration after Logging

The natural regeneration of many species is gap size dependent (Schulze, 1960; Swaine and Whitmore, 1988). Even shade bearers regenerate more frequently in small gaps compared to the forest understorey (Swaine and Whitmore, 1988; Hawthorne, 1993). The sizes of gaps created determines the type of species which regenerate and the extent of natural regeneration. Medium sized openings resulting from felling gaps and skid trails favour the natural regeneration of most of the economic timber tree species, many of which are non-pioneer light demanders, compared to other gaps. Small (branch or small tree fall) and large (multiple tree fall, haulage roads and loading bays) results in reduced regeneration and a decline in the economic value of the tropical high forests of Ghana (Hawthorne, 1993; Swaine *et al*., 1998). This underscores the importance of gaps in regeneration (Hartshorn, 1978; Whitmore, 1990). Timber harvesting affects the forest micro-environment (Chazdon and Fetcher, 1984; Jans *et al*., 1993) and also stimulates the growth and regeneration of tree species.

A study by Swaine *et al*. (1998) which focused on damage immediately following timber exploitation show that disturbances due to logging markedly reduce the pre-existing tree seedlings in felling gaps and skid trails. However, enhanced regeneration was observed in small gaps and skid trails 3 years after timber harvesting in Bia-South Forest Reserve (Hawthorne, 1993) and 15 years after timber harvesting in wet and dry forests (Appiah *et al*., 1998). This is probably because, the stimulation of new seedling establishment significantly exceeds these losses due primarily to the local enhancement of light, the principal limiting factor for plants in forest.

The most abundant class (diameter size) of tree species following regeneration will be the one adapted for the predominant gap sizes (Denslow, 1984).

More advanced regeneration was observed in the wetter forests compared to the drier ones for similar logging operations. This is probably because of the higher rainfall and greater density of seed trees following logging in the wetter forests (Swaine *et al.*, 1998).

Tropical forest tree species differ markedly in their tolerance of shade and their ability to respond to changes in irradiance. The responses of species to variation in irradiance can be studied by growth analysis (Fetcher *et al.*, 1983, Mitchel & Woodward, 1988), using shadehouses (Popma & Bongers, 1991; Osunkoya *et al.*, 1994), gaps created in the forest (Chazdon, 1986; Brown, 1990) or by light response curves in which changes in the rates of photosynthesis and transpiration are measured instantaneously in the same seedling under varying irradiance (Oberbauer & Strain, 1984; Kwesiga & Grace, 1986). The latter approach records the rapid responses of existing leaves and photosynthetic apparatus to changes in light, usually diffuse and neutral in spectral composition (high red:far-red ratio). Growth analysis may be done in shade houses (usually with neutral shade) or in the forest by creating canopy openings of different size, effectively using natural shade where light quality varies with irradiance. In theory, experimental conditions can be more closely controlled and more precise questions addressed by the approach of measuring photosynthesis, but it is very difficult to use the results to predict outcomes for tree seedlings growing in forests. Forest growth analysis experiments are effective at answering questions about how trees will respond to canopy opening, but are less effective at determining which of the changed environmental variables are the cause of the seedlings' response.

Based on field experience of tree growth and more particularly the distribution of young seedlings in different forest light environments, it has been possible to define fairly robust classifications of species according to the light requirements (Hawthorne & Musah, 1993; Swaine & Whitmore, 1988). The simplest classification divides tree species into pioneers (requiring gaps for seedling establishment and growth) and non-pioneers (able to establish and grow in forest shade). Growth analysis and photosynthesis measurements have shown how these contrasting species guilds differ in growth physiology. Pioneers have high dark respiration, high compensation and saturation points and high quantum efficiency. These characteristics give them substantial flexibility for growth in different light environments, but not sufficient for survival in deep forest shade - shade tolerance appears to be sacrificed for the benefit of very rapid growth in high irradiance. By contrast, non-pioneers have low dark respiration, low compensation and saturation points and show relatively little increase in growth when irradiance increases. Their forte is growth and persistence in deep forest shade. These differences are well exemplified by Kwesiga & Grace (1986).

Differences amongst tree species responses to irradiance as determined by such experiments offer the possibility of predicting seedling growth in canopy openings in natural forest. However, forest gaps differ not only in irradiance, but also light quality, humidity, air temperatures and water balance - many potential causes to confound the predictions based on light. Thus it is important to test the applicability of experimental results by trials in the forest. Since environmental conditions differ significantly between forest types, we must also test in more than one type.

Exploitation of tropical forest for timber causes canopy opening, leading to changes in microclimate (Minckler *et al.*, 1973, Vitousek & Sanford, 1986) which influence the remaining trees. Reduced competition, principally for light, allows increases in growth rates for some of the remaining trees, but also to an increase in tree mortality (Primack *et al.*, 1985). For tree seedlings, similar effects occur, but with greater magnitude (Brown, 1990). These microclimatic changes vary with the size of canopy opening, so that the manner and intensity of logging operations can have a profound influence on the recovery of the forest.

Changes in microclimate are driven by differences in the radiation incident in the forest so that incident radiation and other microclimatic variables are closely correlated (Whitmore *et al.*, 1993). Changes in microclimate between canopy gaps of different size are thus fairly predictable: in large canopy openings with high irradiance, the increases in air and surface soil temperatures, in red:far red ratio, and reduction in humidity, are greater than in small openings (Whitmore *et al.*, 1993; Brown, 1993). These physical processes mean that gap size is most appropriately measured as total radiation, though the dependent microclimatic variables, which may be easier to measure, can be used as surrogates. Brokaw's (1982) measurement of gap area is a widely used surrogate, but is not linearly related to irradiance and is therefore inaccurate for small gap sizes and for comparing forests of different stature (Whitmore *et al.*, 1993). Many studies on gap microclimates are restricted to one kind of forest, though it is expected that different kinds of forest will have different microclimates as a result of differences in macroclimate, stature, canopy density and seasonal variation.

Reproduction, Dispersal and Recruitment

Much of what needs to be known about forests, in a way which will facilitate understanding of empirical results on logging damage, is at the species by species (autecological) scale. The literature and inventory data on the autecology of Ghanaian trees is reviewed in Hawthorne (1995). Community-level regeneration studies will benefit from the resurrection of some silvicultural literature, e.g. Lamb, 1940; Webb, 1948; Macgregor, 1948; Lancaster, 1954; Letouzey, 1957; Quist-Arcton, 1958; Sawyer, 1960; Alexandre, 1977, 1978; Lowe 1984; Corbassion & Souvannavong, 1988.

Proximity of disturbed areas to remnant forest patches with ‘seed trees’ promotes more rapid recovery, particularly in species composition. Dispersal syndromes are potentially of great significance to logging prescriptions, especially concerning guidelines for retention of seed trees. When considering the distance that a tree can expect to project its offspring, it is profitable to group species into groups with similar dispersal syndromes (Alvarez Buylla & Martinez-Ramos, 1990; Appanah & Mohd.-Rasol, 1995; Augspurger, 1986; Augspurger & Franson, 1987; Augspurger & Hogan, 1983; Beer & Swaine, 1977; Denslow *et* *al.*, 1990; Howe & Smallwood, 1982; Keay, 1957; Kitajima & Augspurger, 1989; Van der Burgt, 1997).

Tree fruiting phenology is perhaps less significant where there is some temporal buffer for the regeneration, either in a soil seed bank (Cheke *et al.*, 1979; Epp, 1987; Hall & Swaine, 1979; Hopkins & Graham, 1983; Viana & Anderson, 1990), or in the seedling 'bank' (i.e. established seedlings) which will however be more susceptible to logging damage. Very few timber species, a subset of the pioneer guild, occur in the seed bank in Ghanaian forest, including *Milicia, Nauclea (*Kyereh *et al.*, 1999), and probably *Hallea* spp. in swamps.

Variation in seed production capacity occurs on many levels (Baur & Hadley, 1990; Schuppe, 1990) which ought to influence differential tree retention. Integration of seed dispersal and dynamics in the bigger picture of tropical forest regeneration (e.g. Whitmore, 1996) is still a long way from providing many practical solutions. We need more of these studies if we are to make much headway in using such research to guide logging practices.

When the interaction between dispersal distance and stand dynamics are considered, various other trends have been examined - for instance the role of the Janzen-Connell 'escape' hypothesis, whereby seedlings distant from parents perhaps have a greater chance of survival, either due to density dependent mortality (Condit *et al.*, 1994) or distance (from parent)-dependent mortality (Connell, 1971; Howe and Smallwood, 1982; Hubbell, 1980; Janzen, 1970). In many cases, the escape hypothesis has been supported or partially supported e.g. depending on annual variations or scale of analysis (24 studies reviewed by Clark & Clark, 1984; Cintra, 1997). For example, rodent dispersed species including *Carapa procera* are dispersed and hoarded up to tens of metres from mother trees (Forget, 1990), but the final distribution of successful regeneration is strongly shaped by other factors such as soils or canopy gaps.

As the number of variables studied increases, this subject area merges considerably with others, e.g. the already complex issue of guilds and gaps (Alexandre, 1977; Augspurger, 1983 & 1984; Augspurger & Kelly, 1984; Augspurger & Kitajima, 1992; Forget, 1989, Lieberman & Li, 1992; Lopea & Ferrari, 1994; Loubry, 1992). In some cases, seed-centred studies have focussed on these and related issues in the context of the effects of logging or efficiency of silvicultural systems (Appanah & Manaf, 1990; Appanah & Mohd.-Rasol, 1991 &1995; Gorchov *et al.*, 1993; Hammond *et al.*, 1996; Hostettler, 1996; Plumptre *et al.*, 1994; Putz, 1983).

One approach that has been used to predict recruitment is to calculate the proportion of recruited species as a function of stand basal area, site productivity and the relative abundance in the stand. Alder (1995) notes that it is logical to expect a consistent relationship between the basal area removed and the number of trees recruited (after a lag), because basal area losses correlate directly with crown area lost, and hence growing space created. Recruits are of similar size so the number of recruits will be proportional to the growing space available.

Various other autecological subtleties, such as the implications of dioecy (Lawton, 1955; Kigomo *et al.*, 1994), should be accounted for in the formulation of yield guidelines aimed at protecting seed trees (presumably twice the density of functionally dioecious trees would, in general, be needed as seed trees if males tend to equal females in number).

Forest Cover and Long Term Site Potential in Ghana

The size class distribution of tropical forests shows a geometric decrease in number of trees with increasing tree size. This distribution pattern was also observed by Rollet (1978) for tropical rain forests outside Africa. Generally, size class distribution patterns in the tropics have been influenced by the number and frequency of canopy gaps (Golley, 1983), severe disturbance of the forest stand in the past (Rollet, 1978) and the intrinsic physiological and ecological characteristics of the tree species (Jonkers, 1987). Logging also opens up the forest canopy which upsets the natural balance of the forest ecosystem resulting in an increased impact on the long-term functioning of the ecosystem (White and Pickett, 1985). However, the extent of the impact depends on the intensity, frequency and duration of logging.

Uncontrolled logging results in the removal of up to 3 trees ha^{-1} in Ghana (Agyeman *et al*., 1995) and 2 trees ha^{-1} in Cameroun (Duiker and van Gemerden, 1989) which affects up to 13% and 20% of the total area in Ghana (Hawthorne, 1993; Agyeman *et al*., 1995) and Cameroun (Duiker and van Gemerden, 1989) respectively. A higher logging disturbance was recorded in Cameroun compared to Ghana even though less trees were removed because of the larger diameters of the felled trees. For example, most of the trees felled in Cameroun were greater than 100cm dbh whereas those felled in Ghana were above 70 cm dbh (Agyeman *et al*., 1995; Duiker and van Gemerden, 1989).

Generally, logging damage is significantly correlated with scale of operations or felling intensity (Swaine *et al*., 1998). Increasing the felling intensity from 2 to 4 trees ha^{-1} resulted in a 300% increase in total areas affected by logging in Bura and Draw River Forest Reserves in the moist forests of Ghana (Agyeman *et al*., 1995). A study on the impacts of logging (ITTO PD 179/91) in Ghana shows that removing 2.6% trees ha^{-1} resulted in a treefall damage of 8% and skidding/haulage road damage of 5%. Removing twice as many trees in Sapoba Forest Reserve in Nigeria with a vegetation type similar to that of Ghana resulted in a logging disturbance of about 50% of the total forest area (Redhead, 1960) which is about four times that of the disturbance observed in Ghana. Jonkers (1987) also observed that logging damage increases exponentially with felling intensity in a tropical rainforest in Surinam.

The type of damage inflicted on the forest depends on the harvest intensity. Gullison and Hardner (1993) used simulation model to investigate the relationship between harvest intensity and forest damage. At low harvest intensities, most forest damage occurs from the construction of main roads as harvest intensity increases, secondary damage from skid trials and tree felling comes to dominate forest damage. Generally, less damage results to the forest for a given harvest volume if the harvest area is reduced and harvest intensity increased. The extent of tree damage is influenced by the type of logging operation. For example, total number of trees damaged due to haulage road and skid trail construction were higher than that of felling timber trees. This may be due to inefficient extraction machinery and working practices (Agyeman *et al.*, 1995).

Ofosu-Asiedu *et al*. (1993) noted that on average about 4 commercial timber trees between 10-50cm dbh are completely destroyed for every 100m of skid trails constructed. The high tree damage may be related to the large sizes of the skid trails and haulage roads which are made during extraction. The average skid trails were wider than what is prescribed in the logging manual of the Ghana Forest Service. There were also more loading bays per compartment than what is specified in the logging manual. The type of damage due to felling and skidding are different. Felling affects trees of all size classes while skidding mainly affects trees < 20cm dbh (van der Hout, 1996).

Logging disturbance and tree damage were found to be greater in wet compared to dry tropical forests (Ofosu-Asiedu *et al.*, 1993, Agyeman *et al.*, 1995). These differences may be attributed to the fact that larger trees were felled in the wetter forests as is evident from the larger gap sizes and larger mean volume of the felled trees observed from the results of Swaine *et al*. (1998). Another reason is that most areas in the wetter forests have been logged once (first rotation felling) whereas most of the drier forests have been logged at least twice. Incidentally, the wetter forests are richer in floristic composition and have a greater percentage of fragile environments that need to be protected. Since these areas also have greater logging disturbance and tree damage per unit volume of wood harvested, there is the need for stricter logging controls in the wetter forests compared to the drier forests. In practice, however, the manual of procedures of forest management in Ghana indicates that a higher felling intensity should be carried out in wet and moist forests (up to 3 trees ha^{-1}) compared to the drier forests (up to 2 trees ha^{-1}). This is probably because the drier forests are subjected to frequent annual fires which have degraded the forests and caused excessive canopy opening. A high felling intensity therefore, predisposes these drier forests to much more severe fire attacks in subsequent years.

Biodiversity of Residual Forest

The main threats to biodiversity in the tropics include increased incidence of annual fires, increased exploitation, and clearing of forests for agriculture (Hawthorne, 1994). Logging activities may result in the disappearance of species thus reducing species diversity and the potential of the forest (Abdulhadi *et al.*, 1981). Uncontrolled logging has considerable impact on biodiversity conservation, forest structure and species composition and may lead to loss and fragmentation of forests (Foaham and Jonkers, 1992).

Selective logging in some sense mimics natural gaps such as tree falls, or chablis (Gormley, 1997) and therefore do not result in more diverse forests (Brown and Press, 1992). Over 70% of felling gaps created by small loggers at Bura and Draw River Forest Reserves in Ghana were less than $400m^2$ (Agyeman *et al*. 1995). Such small gaps randomly damage or kill large and small trees of all species (Johns, 1988) and tend to enhance the structure and floristic and faunistic diversity of the forest (Laird, 1995; c.f. Gormley, 1997). However, large felling gaps, up to 1000 m^2 which tend to simplify ecosystems and subsequently reduce biodiversity were also observed after exploitation though infrequently (Agyeman *et al*., 1995).

Selective logging of mature or superior trees generally causes genetic depletion, consequent loss of potential food sources and disease control, reduction in the stability of ecosystems and a loss of resilience against catastrophes. The removal of seed trees also reduces the potential of the forest to regenerate after logging. The disappearance of species or the alteration of species compositions in ecosystems may cause irreversible losses of natural resources. An increase in the species that are currently being utilised may lead to loss of intra-specific variation, especially in those timber species for which the regeneration requirements are incompatible with silvicultural system and/or felling cycling. This is probably because timber exploitation is known to exert a negative selection pressure on the species harvested as the most vigorous and well-formed individuals are taken and the lesser quality individuals are left to produce seed (Oldfield, 1990).

The impact of logging on forest fauna is similar to that on flora and depends on the ecology of particular species or group of species. Logging also alters the habitat of wildlife by changing or destroying nesting, feeding and breeding sites. According to Myers (1988), forest disturbance affects animal populations even more than plant species, as animals often require large ranges. Since different silvicultural systems produce forest stands with different forest structure, their impacts on animals varies depending on animal habitat requirements and ability to recognise logged forest (Gullison and Hardner, 1993). According to some local communities in Ghana the noise of logging machinery chases away most mammals and birds (Gronow, J. personal communication).

Another impact of timber harvesting is that on insects. The extent of human interference on the forest ecosystem, especially through logging, determines the risk of pest outbreak (Gray, 1972; Wellman, 1972). This is probably because the degree of devastation by pests is influenced by the complexity of the ecosystem (Cobbinah, 1997) because of selectivity. The more complex the ecosystem the less likely will be the incidence of pest outbreak. For example, the potential for pest outbreaks increase from primary forests through secondary forests to monoculture plantations (Cobbinah, 1997).

Fire

Generally, the incidence of fire increases with forest disturbance caused by logging and thinning operations (Beaman *et al*., 1985; Berthault, 1990). Heavily opened up areas suffer the most from fire damage. Hawthorne (1994) observed that logging has exacerbated fire damage in Ghana. The fire damage in Ghana may be linked to climatic changes, but one cannot simply dismiss current levels of fire damage as part of a natural cycle. The vegetation of heavily logged forest a few years after logging is obviously more prone to serious fire damage (c.f. Hawthorne, 1994). At ground level it feels drier and hotter and there are also more thin stems close to the ground in forest gaps than in undisturbed forest understorey. Fire affects the structure and composition of the vegetation and is now by far the greatest threat to the long-term productivity, genetic wealth and general health of forests in Ghana.

Bush fires in Ghana have been experienced for centuries in both savannah and forest areas, with the destruction of thousands of acres of cocoa farms, food crop farms, villages and trees. Bush fires impoverish the soil by destroying organic matter in the soil, and increasing leaching, wind and water erosion. Bush fires also have significant influence on the composition of the present forest canopy and serious consequences for forest regeneration (Orgle, 1994). Mortality caused by fire is greatest for small trees, whilst more large trees are killed by drought. This thinning allows rapid recolonization, especially by marantaceous and zingiberaceous forbs and pioneer trees. Recurrent fires impede recovery of burnt forest (Hawthorne, 1994). Fire-affected forests generally has a higher proportion of deciduous trees, thick bark, hard slash, deep roots and absence of buttresses and stem fluting compared to closed canopy forests without fire (Kielland-Lund, 1982).

Severe fires can be limited by preventing excessive logging (Hawthorne, 1994). Beaman *et al*. (1985) has shown that fires in Sabah, Malaysia, following dry years, were almost six times more common in logged forest than in unlogged forest. Ecologically sound logging practice should limit the effects of subsequent fires. This can be achieved by limiting the total number of trees removed per compartment and by limiting the number of adjacent trees felled. These two restrictions should be enforced in fire-prone areas. In addition, as most fires probably enter the forest from bush fires in vegetation surrounding the reserves, logging and other forms of canopy disruption should be prohibited in buffer zones insulating each forest block (Hawthorne, 1994). The prevention of bush fires by education, use of improved agricultural practices and enforcement of bush fire laws should be implemented by all countries in fire prone areas. (Korem, 1985).

Apart from logging, changes in global climate has also been a major factor influencing the incidence of forest fires. For example, the drought of 1982-3 resulted in widespread occurrences of fire in most parts of Africa (Sanford *et al*., 1985; Beaman *et al*., 1985). The incidence of fire is extremely high at the transition zone between forests and savannah in Ghana (Brookman-Amissah *et al*., 1980). Other factors influencing forest fires in the country include, slash and burn agricultural system, hunting and palm-wine tapping. Drought and other forms of forest degradation results in reduced canopy cover leading to a drier, more inflammable forest. This has made them highly susceptible to fire. According to Swaine *et al*. (1997), drought and fires in the humid forests of Africa are not new and may be attributed to the long lasting effects of severe droughts that have hit the region in the past.

Soils

A number of studies have indicated that soil compaction is a greater problem following logging than soil erosion (Tachie-Obeng, 1995; Appiah *et al*., 1998), especially viewed against the background that current road construction activities of large companies tends to cause a cumulative loss of production over several felling cycles due to serious soil compaction. Timber harvesting as currently practised in tropical Africa leads to slight reduction in soil productivity in felling gaps (Tachie-Obeng, 1995) since all the branches, leaves and almost 50% of standing tree volume are left in the forest as residue. However, significant changes in soil productivity were observed on haulage roads and skid trails (Tachie-Obeng, 1995). In a similar study, Gent *et al*. (1983) observed significant changes in soil physical properties from the surface to the 30cm depth in the skid trail plots following logging, however, significant changes in soil properties in treefall gaps were limited to the upper 15cm of soil.

Another major impact of logging is the removal of the top soil during log dump, haulage road and large skid trail construction resulting in loss of soil fertility. Congdon and Herbohn (1993) observed that nutrient concentrations in felling gaps were depressed in wet tropical forests compared to unlogged forests even 25 years after selective felling. Conventionally, harvesting removes about 5-30% of the total nutrients taken up in the above grand stand (Stone, 1968). There is a world-wide concern that increased removal of tree biomass with its nutrient content causes a decline in soil nutrient and forest productivity (Jordan, 1985). Additionally, opening up the canopy through logging results in higher day time temperatures and reduced day-time humidity on the forest floor (Schulz, 1960) which invariably influences nutrient cycling.

Tropical forests are considerably capable of compensating for slight reductions in soil nutrient content arising from relatively low logging intensity by taking up nutrients directly from rainfall and from the air by means of nitrogen fixing organisms (Jordan and Herrera, 1981). However, as logging intensity increases nutrient loss also increases and it takes a much longer felling cycle for the forests to cope with such loss. With the present increasing and persistent destruction of the tropical forest, the entire forest ecosystem may not be capable of sustaining itself if realistic measures are not taken to reduce nutrient loss through tree harvest (Nye and Greenland, 1990).

Timber Harvesting and Management in the Tropics

The general objective of forest management in the tropics is *“the sustainable production of timber to provide a perpetual flow of wood products to domestic and export markets and to provide revenue for the resource owners; and to fund forest management whilst maintaining environmental quality and social responsibility”*. Thus forest management in the tropics has traditionally concentrated on timber harvesting and it is these systems that are best developed in tropical Africa and Asia. Timber management is based on the principles of sustained yield management using low intensity selection harvesting and natural regeneration as a silvicultural tool.

Timber production from the tropics has largely been based on two main management systems, namely the Uniform and Selection systems. The Uniform system was applied with the aim of producing an even-aged forest stand made up of only a few economic timber species. This idea is laudable as it makes management simpler. Its major drawback, however, is that it does not allow the floristic richness which is characteristic of natural tropical forests, to be maintained. The system also tended to be rather expensive in its application and was consequently abandoned (Osafo, 1970; Alder 1993).

The Selection system, on the other hand, seems to maintain the natural composition of the forest, thereby ensuring biodiversity conservation and constant supply of both timber and non-timber produce. It also has a higher potential for meeting the changing needs of people with time. A characteristic feature of this system is the removal of single trees of economic species scattered over a given area of the forest. The removal is controlled by a felling cycle, diameter limit and annual production quota (the annual allowable cut). This system is widely applied in the tropics but has undergone modifications in several aspects of its application. The current thinking is that logging alone could be used to improve the condition of the selection forest. What needs to be done is to develop more efficient management control measures by determining sustainable felling cycles, realistic felling quotas (allowable cut) and more appropriate exploitable diameter limits for the various species to ensure that the forest resource is managed sustainably.

The Selection System is currently the most widely adopted forest management practice in the tropics. For example, the selection system continues to be the main management system in Ghana. Generally, the system involves commercial logging with or without regeneration or silvicultural treatment. The logging, consist of the removal of single economic tree species scattered throughout the forest. The forests are divided into forest management units (FMUs) with a number of more or less equal compartments for ease of logging and purposes of controlling exploitation. The annual felling takes place in one or more compartments depending on the length of the felling cycle and total area of the forest. Felling cycles ranging between 15 and 40 years have been applied over the years in the tropics. Timber exploitation is generally preceded by a stock survey during which a 100% count of all commercial timber species with minimum dbh of 30 cm was made, especially in tropical Commonwealth Countries. The concessionnaire is allowed to exploit a certain number of trees or basal area per unit area prescribed by the management plans for the given forest.

However, the ability of the Selection system to ensure sustainability of the tropical forests has not been adequately tested experimentally. It has been observed that logging based on the Selection System alone (i.e. selective cyclical cutting), without any pre- or post-logging silivicultural treatment reduces the stocking density and species composition (Alder, 1990; Adam *et al.*, 1994). This implies that commercial logging should always be preceeded by or followed with some form of silvicultural treatment. For instance climber cutting has been recommended in areas with good natural regeneration.

In spite of the significant contribution of timber harvesting to the national economy of tropical countries, the sector is dependent on the exploitation and marketing of a relatively few prime timber tree species. The small number of species that are commercially exploited tends to make profitable logging and sustained yield management difficult to attain (FAO, 1993). For example, only about 7% of tree species in the tropical forests of Ghana were being exploited prior to 1990s, and in addition, over 70% of timber exported in 1990 was from only two species (FPIB, 1991). A similar situation is found in Cameroun where 86% of timber harvested is from 15 species out of 56 commercially exploitable species (Evans, 1990). The restriction of exports to a relatively small number of species may be attributed to the fact that most importers from industrialised countries are reluctant to import lesser-known species from Africa probably because of the availability of adequate supplies of the more established species from a variety of African countries (Agyeman *et al.*, 1997). Secondly, consumer preferences and tastes are slow to change (Smith and Eastin, 1990). The failure of producer countries to successfully introduce new tree species and industrial products is largely the result of inadequate preliminary marketing analysis and the failure to develop effective marketing strategies (Cooper, 1979). Efforts are being made to utilise more species for both local and export markets. Governments of most tropical African countries are thus encouraging their timber industries to expand the species base in order to increase the net revenue (TEDB undated).

Stock Surveys

A stock survey is usually undertaken before permission is granted to a timber contractor to exploit a compartment, which is the basic unit of forest management in Ghana. The main purpose of the stock survey is to know the current stocking of exploitable trees as well as that of the replacement crop. It is also to provide information on the location of the exploitable trees so as to ensure proper road and skid trail layout. The most important use of the stock survey data is to calculate the volume of the exploitable trees and mark out the selected trees. It involves a 100% enumeration of all commercial timber species above a certain minimum diameter, e.g. 30cm dbh in Ghana (Baidoe, 1970) and 42cm dbh in Liberia (Parren and de Graaf, 1995).

In addition to the stock map, a stand table is prepared showing the tree numbers recorded according to species and diameter classes. The stand table provides the stem numbers needed for the yield calculation and the stock map helps in yield selection. The advantage of using a stock survey map to determine yield is that it gives an indication of species richness, density and distribution for different concessions in the same forest type and for different forest types. A properly executed stock survey generally enhances sustainable management of the forest.

Felling Limits

The application of a diameter felling limit has been considered as one of the useful timber production control tools applicable to both reserved and off-reserve forests even though other methods based, for instance on basal area or volume removed per unit area is deemed more efficient. Minimum felling limits are supposed to define the point of maturity of various species suitable for timber and other uses, allowing for the removal of only mature trees. Silviculturally, the effect of applying a felling limit is that it allows the residual stand to be composed mainly of productive trees (i.e. trees that are vigorously growing). Consequently the basal area or volume stocking increases over the period of the felling cycle, and the production of viable seeds is enhanced, thus ensuring adequate natural regeneration (Adam, 1996). For wood processing purposes, the major effect is the assurance of sustainable supply of good quality logs (i.e. trees occurring in the exploitable diameter will have good quality wood). Therefore in determining appropriate felling limits for various species factors such as stem diameter or volume increment (i.e. growth), tree mortality and wood quality of different size classes should be taken into account.

In Ghana the use of felling limits dates back to 1907, in the early days of timber exploitation in West Africa. There have been revisions of these felling limits in 1910, 1958, 1970 and recently in 1989 (Ghartey, 1992). Other countries in the West African sub-region, notably Liberia, Côte d'Ivoire and Cameroon, have similarly adopted felling limits as a control tool, with some variations in limits applied for similar species in the various countries. Generally, however, the minimum felling limits adopted in Ghana have been higher compared with those applied in these other countries.

The basis for the felling limits applied in Ghana during the colonial era is not known, but according to Ghartey (1992), the limits prescribed in 1970 under the salvage felling regime were based on economic and physiological over-maturity. The prescription of the 1989 felling limit has, however, been based on the relative abundance of a particular species and the degree to which it is threatened by extinction (Ghartey ibid.).

Yield Formula

The actual number of trees that can be exploited within a compartment is regulated through the use of a yield formula which allows the removal of individual species growth achievable over the period of the felling cycle (Planning Branch, 1995a). For example, in Ghana, there are two variants of the yield formula, namely; standard yield formula which is $Z = 0.5Y + 0.2X$, and reduced yield formula which is $Z = 0.25Y + 0.2X$, where Z = number of trees to be removed above the felling limit; Y = number of trees in the diameter class equal to or above the felling limit and X = number of trees in the diameter class immediately below the felling limit. The normal yield formula is applied to red and pink star species in the wetter forests while the reduced yield is applied to scarlet star species and dry forest areas.

Harvesting is only permitted in compartments where the total stocking of exploitable timber tree species with stem diameter greater than 50cm is higher than the average stocking of the vegetation type within which the compartment is situated. However, harvesting is not allowed if the condition index for the compartment is less than 40% in the wetter forests and less than 60% in the drier forests (see Table 1).

Red Star species are common but with exploitation rates greater than 200% of the allowable cut. These species need careful harvesting controls and some tree by tree and area protection.

Pink Star species are common. These species have rates of harvest between 50-200% of their allowable cut. Pink Star species also include non-abundant species of high potential value.

Scarlet Star species are common with exploitation rates less than 50% of their allowable cut. Pink Star species also include non-abundant species of high potential value. The condition index is a numerical expression of the condition of the forest understorey within a compartment. The index is a measure of the health and regenerative capacity of the forest. The yield from a forest is varied depending on the condition index.

Table 1: Criteria used for the selection of yield formula to apply during harvesting of a compartment in the different forest types.

Condition	**Selected Reserves in DS and MS**	**All Other Reserves**
Condition index less than 40%	No Harvesting	No Harvesting
Condition index between 40-60%	No Harvesting	No Harvesting
Condition Score 3 Predominant	No Harvesting	Reduced yield formula
Condition Score 1 or 2 Predominant	Reduced yield formula	Standard yield formula

Annual Allowable Cut

The term “Annual Allowable Cut” - AAC is the maximum volume that can be felled each year without reducing the long-term sustainability of the forest resource. Alder (1989) suggests that a felling intensity of 1.23m^3 ha^{-1} $year^{-1}$ or 50m^3 ha^{-1} per felling cycle of 40 years (equivalent to 3 mature trees ha^{-1} per felling cycle) must be enforced in the tropical high forests of Ghana and probably West Africa in order to achieve sustainability. The length of the felling cycle for Ghana (40 years) is similar to that of tropical South East Asia (30-40 years) but higher than that of most tropical Latin American countries (above 10 years) (c.f. Gormley, 1997). There is no long term evidence as to which particular felling cycle is sustainable although obviously the longer the felling cycle the greater the recovery.

Sustainability of Current Timber Harvesting Practices in the Tropics

Sustainable timber harvesting is the use of natural forest which maintains forest environmental services and biological qualities substantially unimpaired, and implies that similar amounts and types of products (dimensions, quality, species) continue to be harvestable at periodic intervals in perpetuity (Seydack, 1995). Therefore, for harvesting to be sustainable it must be organised in such a way that it remains within the renewability capacity of the forest system both in respect of growth as well as the success and type of regeneration.

Forest management has traditionally concentrated on timber harvesting and it is these systems that are best developed in the tropics. Timber management is based on the principles of sustained yield management using low intensity selection harvesting and natural regeneration as a silvicultural tool (c.f. Planning Branch, 1995b). Currently, tropical African countries have minimum felling limits ranging between 50cm dbh and 70 cm dbh. Additionally, mean felling intensity ranges between 0.33m^3 ha^{-1} and 0.50 m^3 ha^{-1} in tropical Africa (Parren and de Graaf, 1995), whereas South East Asia and Latin America have a range of between 0.8 m^3 ha^{-1} and 1.1m^3 ha^{-1} (Plumptre, 1996; Gormley, 1997). A tight log monitoring system has been developed in most countries which tracks trees from stock survey maps through felling and extraction, using in most instances chain of custody certification procedures. Harvest controls systems have been developed to ensure that all timber exports are sourced from sustainably managed forests. In addition, efforts have been put in place to minimise logging residue generation and promote improved recovery and value-added production by encouraging efficient secondary and tertiary processing (FDMP, 1996).

The dependence of tropical timber trade on a few species has resulted in the “creaming” of a few prime species, a reduction in the raw material base and an increase in the cost of sawmilling operations. It is well known that the future security of wood source from tropical forests depends on sustained production of timber. As trade continues to evolve, there will be greater pressure for higher yields. There is therefore the need for a comprehensive programme to encourage the utilisation and marketing of Less Used Species (LUS). This will provide greater opportunity and incentive as well as income to forest managers leading to greater feasibility in silvicultural planning and responsibility towards maintaining sustainable forest management (SFM).

LUS are timber tree species which show promising market potential. Such species tend to be characterised by

- Flexibility in fitting today's rapidly changing markets i.e. the distribution and exploitable volume of the species are sufficient for market interest.
- (Often) strategically positioned as a substitute to prime commercial species and thus are potentially of high value. However, most of these species may have one or more undiserable characteristics (which may or may not be possible to overcome through improved processing techniques).
- A species for which marketing opportunities arise due to greater processing options, and thus a bulk market, relatively low value species, possibly in competion with plantation production.
- Several terms that have similar meanings to LUS have been used extensively in the literature, namely; commercially less acceptable species ((CLAS) as defined by IUFRO), lesser known species (LKS), new species (NS) and previously unmarketable species (PUS). This project seeks to come out with broadly acceptable definitions of LUS and other synonyms.

Increased harvesting of LUS done on an economically and ecologically sound basis is firmly linked to SFM. This is probably because increased harvesting of LUS invariably leads to increased income part of which can be invested in the development and implementation of SFM techniques.

Consequently the International Tropical Timber Organisation (ITTO) and Governments of some tropical countries have designed programmes to ensure both biodiversity conservation and expansion of the species base, as well as the greater utilisation of lesser used species (LUS).

Presently, many of the tropical timbers, especially LUS are being burnt or otherwise wasted after logging in the reserved forests and conversion of forest lands into agricultural use in off-reserve areas. There is the need to initiate programmes aimed at the sustained utilisation of timber especially in countries where logging volumes or yield are low (Yeom, 1984). It is in line with this objective that the ITTO commissioned the International Institute for Environment and Development (IIED) in 1991 to review knowledge in LUS and evaluate the ecological impact of increased harvesting of tropical timber. The study noted that whereas industrial and marketing aspects of timber have received considerable support, ecological impacts of increased timber exploitation and utilisation have received little attention.

According to Planning Branch (1995b), the promotion of LUS has long since been promulgated as a means to keep the timber industry in business in the face of economic extinction of primary species. It is evidently not wise to use this means for ensuring 'sustainability' of supply and care should be taken to make sure that only species suitable for sustainable exploitation based on natural abundance and growth rates are promoted. Any increase in harvest intensity should be undertaken with greater care since it may lead to substantial ecological damage. For example, in tropical Africa uncontrolled harvesting of timber has resulted in poor regeneration and forest stand condition even 15 years after logging. The large canopy openings, especially logging roads and skid trails created results in a high proportion of pioneers among the regeneration, which are less valuable timber trees compared to light demanders and shade bearers (Appiah *et al*., 1998). There is therefore the need to ensure that economic concerns are carefully balanced with ecological considerations in timber management in the country.

The Way Forward

The key to providing meaningful forecasts of the future is understanding the past and recognising factors that have shaped patterns of land use, forest utilisation, benefits sharing, trade, investment and other interrelated forests. Analysis of the current status and trends has led to the identification of themes that are likely to be important in determining the future of tropical timber harvesting.

(i) *Pressures for sustainable management will continue to gather force.*

While some progress has been made in this direction, more is needed to satisfy the principles of sustainable forest management. In particular efforts should be made in reducing harvesting and processing waste. ITTO demand for timber products to be sourced from sustainable managed forest in member countries is the immediate challenge.

(ii) *Demand for social equity will increase.*

Although there is a general recognition of the roles of forests in local people livelihoods, in practice however, the social aspects of forestry are often neglected or sacrificed in pursuit of financial expediency. It is expected that demands for greater participation and responsibilities and benefits will intensify in the face of the dwindling resources.

(iii) *Increasing restrictions on access to forests through physical and regulatory constraints.*

With deforestation rate of 1.3% and overall forest quality decline, it seems evident that the future holds greater physical resource constraints.

(iv) *Timber trade will remain important.*

In spite of all the above trade in timber products will continue to be important through its contributions to foreign exchange earnings and GDP. Wood demand in the domestic market will also increase due to population growth and other factors. There will be a shift from the so called prime species to lesser-used species and from red woods to light coloured wood species. These development has already started.

Options for the Future

Against the general policy background and factors that are likely to shape the future of timber harvesting in the tropics, the following options have been proposed.

(i) *Improve efficiency in forest harvesting and wood processing.*

Significant economic gains could be

made if the current rates of product recovery from 50% for harvesting, and from about 30% - 45% for log processing could be improved. Examination of case studies from S.E. Asia suggests that harvesting efficiencies could be increased by at least 10%. The scope for improvement in processing efficiency is perhaps even greater than that of harvesting. Improvements in processing efficiency could help to diminish the pressure on the forests by reducing the volume of logs required to manufacture the same volume of products. Presently total wood utilised is approximately 15-30% of the utilisable volume of wood.

(ii) *Promotion and marketing of lesser-used species.*

Out of the recorded 680 woody, plant species in Ghana's forests, 240 grow to timber size of above 50cm dbh. So far 66 species have been marketed (Kuffour unpublished). Of these 18 species are regularly traded and 8 species representing 90% of the traded species. Over-reliance on small range of species has led to imminent threat on stocking of 15 species (scarlet) a possible economic extinction of about 5 species and significant danger to 17 others (red). In order to reduce imminent danger posed to these species it is important the range of species utilised or traded is broadened through promotion and marketing of the LUS.

(iii) *Increase production from forest plantations particularly on degraded forests lands.*

A relatively new prospect for encouraging investment in plantation is to provide measures for sequestering carbon in exchange for pollution rights under climate change agreements. While specific details are still to be clarified, the Kyoto Protocol lays a foundation for a potential vast new investment in forest plantations. Ghana, for example, needs to negotiate for investment in this area in support of its plantation development and the Forestry Development Master Plan.

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A 2ha plot (200 x 100m) in dipterocarp forest was located subjectively to cover skid trails, cutover and undisturbed forest, and divided into 200 (10x10m) subplots. All trees >10cm dbh were measured, identified and mapped; and % damage recorded. Damage to crown and branches was assessed in 25% bands (following Nicholson, 1958). Stumps were mapped. Saplings (dbh 2-10cm) were sampled within 5x5m subplots of each plot, and diameters measured at 50cm. Seedlings were sampled within 42 1x1m subplots. 21 were on 'bare' ground and 21 on adjacent undisturbed ground along skid trails. All seedlings were identified and counted and % cover estimated. Tractor paths were mapped. Water permeability of soil was measured by timing water infiltration into a tin can with no ends pressed into the soil in each of the 42 1x1m subplots. Reduction of basal area etc. was estimated (36 to 16. 75 m2/ha) by comparing adjacent undisturbed forest (Stem Density fell from 445 to 259 trees/ha). 30 pioneer species invaded; estimated 50 sp. lost. Only 60% of residual trees were undamaged. 18% of trees had crown damage (mostly 75-100%). 23% of trees branch damage, which was generally less severe. 'It is concluded that present logging practices are too damaging to the forest'.

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Seedling crowns of four pioneer species (*Cecropia obtusifolia, Heliocarpus appendiculatus, Piper auritum, Trema micrantha*) were found to be oriented toward diffuse radiation received from the gap, and not toward direct radiation. The mean orientation of the crown, at the whole plant level, was primarily determined by non-random orientation of individual leaves. Study in Veracruz, Mexico.

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Historical data on timber exploitation and forest inventory data were used to assess the effectiveness of forest regulations aimed at ensuring a future crop of marketable trees, from 1900 and 1990. The number of commercial species increased from 3 to 66 species, and felling diameter limits and cutting cycles changed several times. Patterns in exploitation, either in number of species or total stems removed, were unrelated to the application of harvesting regulations. Milling capacity and political instability are thought to have played a larger role.

Adjers, G. , S. Hadengganan, J. Kuusipalo, K. Nuryanto & L. Vesa. 1995. Enrichment planting of dipterocarps in logged-over secondary forests – effect of width, direction and maintenance method of planting line on *Shorea* species. Forest Ecology and Management 73: 259-270.

Adnan, M; Holscher, D. 2011. Medicinal plants in old-growth, degraded and re-growth forests of NW Pakistan. Forest Ecology and Management 261: 2105-2114

Old-growth forest, forest degraded by logging, derived woodland, agroforest and regrowth Forest were assessed for their abundance of 10 locally important medicinal species (highest market value). Recovery of these species was assessed in regrowth forests. Mean medicinal species coverage was highest in old-growth forest (7%), low in forest degraded by logging, derived woodland and agroforest (0.3–2%), and intermediate in re-growth forest (4%). The 10 medicinal species are not characterised into successional guilds, but it seems that they are mainly late successional species. Based on these 10, anthropogenic forest degradation leads to a reduction in the abundance of economically viable medicinal plants for the study region.

Agren, A. 1969. Increment loss in thinned stands caused by modern skidding techniques. Allg. Fostzeitschr. 24: 758

Study in Sweden shown skidding damages roots and reduces increment in nearby trees.

Aguilar-Amuchastegui, N. & G.M. Henebry. 2007. Assessing sustainability indicators for tropical forests: Spatio-temporal heterogeneity, logging intensity, and dung beetle communities. Forest Ecology and Management 253: 56-67

A logging intensity threshold of four trees/ha was identified as a transition to significant differences in forest structural heterogeneity and the richness and diversity of associated dung beetle communities.

Agyeman, V. K. 1994. *Environmental influences on tropical tree seedling growth*. Ph. D thesis. University of Aberdeen, U. K.

Agyeman, V.K., Appiah, S.K. and Siisi-Wilson, E. 1997. A literature review on impacts of increased harvesting of lesser used species (LUS) in the tropical forests of Africa. A Report Submitted to ITTO. 19 pp.

Agyeman, V. K. , C. Turnbull & M. D. Swaine. 1995. Maintenance of biodiversity in the tropical high forests: current research initiatives in Ghana. Abstract: Proc. 10 IUFRO world congress. Pp. 76-77.

Summary of the situation in Ghana. BA Harvest >3. 5 m^2/ha will exceed the forest's ability to regenerate. Gap sizes do have an influence on recovery.

Ahmad, N., M.N. Hasan & A.L. Mohamad (in press) Diversity and density of primates in primary and logged lowland tropical rain forest at Danum Valley, Sabah, Borneo. Biodiversity and Conservation

Aiba, S. I. and T. Kohyama 1997. Crown architecture and life-history traits of 14 tree species in a warm-temperate rain forest: significance of spatial heterogeneity. Journal of Ecology 85: 611-624

Aide, T. M. 1987. Limbfalls: a major cause of sapling mortality for tropical forest plants. Biotropica 19: 284-285.

Limbfalls caused 22.2 and 46.7% of deaths of *Connarus turczaninowii* liana saplings in two years of the study in the Barro Colorado PSP, and caused 4.9% and 3.6% of the plants to lose between 90-100 % of their leaf area. Limbfall damage is thought to disproportionately affect shade-tolerant saplings (cf. pioneer species) because they are slower growing and are smaller for longer. It is hypothesised that limbfall could select for particular branching patterns (sapling architecture), and this could explain architectural differences between pioneer and shade-tolerant saplings.

Aide T.M., Zimmerman J.K., Pascarella J.B., Rivera L. and Marcano-Vega H. 2000. Forest regeneration in a chronosequence of tropical abandoned pastures: implications for restoration ecology. Restoration Ecology 8: 328–338.

Well-cited paper pointing out that structural composition and alpha diversity of secondary forest (40 year regrowth from land that has been used long-term for agriculture) is similar to original forest, but the species composition is different. Little colonisation of shade-tolerant ‘old forest’ species in these plots even after 60 years and in spite of nearby source trees. Alien species overrepresented in the secondary forests cf. original.

Akite, P. 2008. Effects of anthropogenic disturbances on the diversity and composition of the butterfly fauna of sites in the Sango Bay and Iriiri areas, Uganda: implications for conservation. African Journal of Ecology 46: 3-13

Akutsu, K., C.V. Khen, & M.J. Toda. 2008. Assessment of higher insect taxa as bioindicators for different logging-disturbance regimes in lowland tropical rain forest in Sabah, Malaysia. Ecological Research 22: 542-550

Alder, D. 1989. Natural Forest Increment, Growth and Yield. *In*: Ghana Forest Inventory Project Seminar Proceedings. Accra, 29-30 March 1989.

Alder, D. 1990. GHAFOSIM: A Projection System for Natural Forest Growth and Yield in Ghana. Unpublished final Report to Forestry Dept., Ghana. July 1990.

Alder, D. 1992. Simple methods for calculating minimum diameter and sustainable yields in mixed tropical forest. Pp. 189-200 in Miller F. R. & K. L. Adam, (eds.) Proceedings of the Oxford Conference on Tropical Forests.

Optimum diameter calculated from the cumulative age and volume of the survivors from a developing cohort, to produce a MAI per 100 seedlings (MAI%). The maximum MAI% represents the optimum felling diameter for timber production. For three timber species in Ghana, this is c. 60cm DBH.

Alder, D. 1993. Growth and Yield Research in Bobiri Forest Reserve. ODA/FIMP Consultancy Report No. 14. May 1993. 71pp.

Alder, D. 1995a. Growth modelling for mixed tropical forests. Tropical Forestry Papers 30. Oxford Forestry Institute, UK. 231 pp.

Alder, D. 1995b. Preliminary Analysis of Permanent Sample Plot Data. FIMP/ODA/FD Internal Report. August 1995. 30pp.

First analysis of new series data second enumeration, for 66 plots over 2. 5 years, except that many data problems were evident and are highlighted in this report. Problems highlighted include non-use of a tree list at the second enumeration; use of new tree numbers when old numbers were missing and the fact that 75% of measurements are on trees 10-20cm DBH. Increments in ME forests exceeded 1m3/ha/yr for whole stands, but elsewhere increments were often zero or negative. For individual species, average increments (6-7mm. /yr) and mortalities (2.7-2.9%) were higher than previous assessments (mortality of 1.25%). The Interim Yield formula would be unsustainable, except for Pink Star species, and an alternative method using Q ratios is explained. It is recommended that min. DBH is increased to 20cm; tree lists are used; the no. plots are reduced from 600 to 200 and quadrat checksums are added, with the remaining plots allocated to research projects.

Alder, D. & T. J. Synnott. 1992. Permanent Sample Plot techniques for mixed tropical forest. Tropical Forestry Papers 25. Oxford Forestry Institute, UK. 124 pp.

Alexander, I. J. , N. Ahmad & S. S. Lee. 1992. The role of mycorrhizas in the regeneration of some Malaysia forest trees. Philosophical Transactions of the Royal Society B. Biol. Sci. 335: 379-388

Alexandre, D. Y. 1977. Regeneration naturelle d'un arbre characteristique de la foret equatorielle de

Cote d' Ivoire: *Trema guineensis* Pellegr. Oecologia Plantarum 12: 241-262.

Alexandre, D. Y. 1978. Observations sur l'ecologie de *Trema guineensis* en basse Cote d'Ivoire. Cah. ORSTOM, ser. Biol. 13: 261-266.

Alexandre, D. Y. 1982. Aspects de la regeneration naturelle en foret dense de Cote d'Ivoire. Candollea 37: 579-588.

Alexandre, D. Y. & G. H. Tehe. 1980. Le recru apres exploitation traditionelle de la foret dense ombrophile de Tai (Cote d'Ivoire). In Silviculture under extreme ecological and economic conditions. IUFRO meeting, Sept-Oct. 1980. 349-366.

Allport, G. A., M. Ausden, P.V. Hayman, P. Robertson & P. Wood. 1989. The birds of the Gola Forest and their conservation. ICBP Study Report no. 38.

Alongi, D.M. & N.A. de Carvalho. 2008. The effect of small-scale logging on stand characteristics and soil biogeochemistry in mangrove forests of Timor Leste. Forest Ecology and Management. 255:1359-1366

The impact of small-scale cutting of mangroves was examined in three mangrove forests of Timor Leste. After one year forests experienced a 30-50% decline in live stems and a 46-86% loss of above-ground biomass with more canopy gaps between less dense, smaller trees. Concentrations of most particulate nutrients increased in surface soils in the harvested stands, reflecting bark, leaves, twigs, and small branches discarded on the forest floor. Interstitial concentrations of dissolved sulfide, metals, and ammonium also increased due to enhanced soil desiccation (evidenced by increased salinity). Rates of anaerobic soil metabolism (sulfate reduction) declined after the onset of cutting, attributed to the decline in live roots and their metabolic activities. These cutting operations, although small-scale, are unsustainable as these forests are likely to be slow-growing in such highly saline soils.

Alvarez-Buylla, E. R. 1994. Density dependence and patch dynamics in tropical rain forests: matrix models and applications to tree species. American Naturalist 143: 155-191

Alvarez-Buylla, E. R. & M. Martinez Ramos. 1990. Seed bank versus seed rain in the regeneration of a tropical pioneer tree. Oecologia 84:314-325.

Cecropia obtusifolia seeds have a poor survival rate in soil due to predators and pathogens, but rapid heavy turnover due to good dispersal at least up to 86m from parent.

Alvarez-Buylla, E. R. & M. Martinez-Ramos. 1992. Demography and allometry of *Cecropia obtusifolia*, a neotropical pioneer tree - evaluation of the climax-pioneer paradigm for tropical rain forests. Journal of Ecology 80: 275-290.

Ampofo, S. T. & G. W. Lawson. 1972. Growth of seedlings of *Afrormosia elata* Harms in relation to light intensity. Journal of Applied Ecology 9: 301-306.

An Andel, T. 2001. Floristic composition and diversity of mixed primary and secondary forests in northwest Guyana. Biodiversity and Conservation 10: 1645-1682

Andersen, A.N., T.D. Penman, N. Debas, & M. Houadria. 2009. Ant community responses to experimental fire and logging in a eucalypt forest of south-eastern Australia. Forest Ecology and Management 258: 188-197

Andre, T., M.R. Lemes, J. Grogan, & R. Gribel. 2008. Post-logging loss of genetic diversity in a mahogany (*Swietenia macrophylla King*, Meliaceae) population in Brazilian Amazonia. Forest Ecology and Management 255: 340-345

Using eight hypervariable microsatellite loci, a significant reduction in the number of alleles, observed heterozygosity, and distinct multilocus genotype number was found in the post- compared to the pre-logging cohort. The results raise concerns about the conservation genetics of logged mahogany populations where a high proportion of adults are removed from the system.

Anggraini, K., M. Kinnard, & T. O'Brien. 2000. The effects of fruit availability and habitat disturbance on an assemblage of Sumatran Hornbill. Bird Conservation International 10:189-202

Anon. 1947. Phenologie (Phenology) of *Afrormosia elata*. Rapp. Inst. Nat. Etude Agron. Congo Belge.

Appanah, S. 1998 Management of natural forest. Pp 133-149 in Appanah, S. & J.M. Turnball (eds.) A review of dipterocarps, taxonomy, ecology and silviculture. CIFOR, Bogor, Indonesia.

Appiah, M., D. Blay, L. Damnyag, F.K. Dwomoh, A. Pappinen, & O. Luukkanen. 2009. Dependence on forest resources and tropical deforestation in Ghana. Environment Development and Sustainability 11:417-487

Appiah, S.K., Siisi-Wilson, E., Agyeman, V.K., Ortsin, G. And Birikorang, G. 1998. Ecological impact of increased harvesting of lesser-used species (lus). ITTO PD 33/95. Report submitted to the Internation Tropical Timber Organisation (ITTO), Yokohama, Japan. 53 pp.

Appanah, S. & A. M. Mohd. -Rasol. 1991. Fruiting and Seedling Survival of dipterocarps in a logged Forest. Journal of Tropical Forest Science 6: 215-222.

Selective logging in Malaysian Dipterocarp forest of 50-60 dbh. No attention to regeneration that will form later cuts. Fruiting was poor but predation lower than expected. Seedlings from post logging fruiting survived well and so have positive implications for management of Logged forests.

Appanah, S. & A. M. Mohd. -Rasol. 1995. Dipterocarp fruit dispersal and seedling distribution. Journal of Tropical Forest Science 8: 258-263.

Logged dipterocarp forest in peninsular Malaysia. 90 degree wedge plots of 225m radius divided into 5m sectors. Winged seeds of *Shorea* and *Hopea* species studied weekly and compared with adjacent wedge a year later. Seed density generally rises to 25m from tree then begins to fall as distance increases.

Appanah, S. & M. R. A. Manaf. 1990. Smaller trees can fruit in logged dipterocarp forests. Journal of Tropical Forest Science3: 80-87.

In hill dipterocarp forests trees 15-<50 cm dbh are left to provide seeds and for the next crop. Fruiting of the smaller trees in logged forest was compared to undisturbed forest. In recently logged forest, smaller trees (25+ cm) tended to fruit. Equivalent sized individuals did not, though larger ones (35+) did, in unlogged forest. It may be because of changes in temperature fluctuation promoting flowering. (But, see Thomas & Appanah, 1995).

Appanah, S. & F. E. Putz. 1984. Climber abundance in virgin dipterocarp forest and the effect of pre-felling climber cutting on logging damage. The Malaysian Forester 47: 335-342.

In 13 ha of virgin dipterocarp forest of Sungai Tekam Forest Reserve, Pahang [Malaysia], there were an average of 376 climbers/ha > 2 cm dbh (diameter at 1.3 m from the ground). Cutting of climbers before logging reduced the number of trees pulled down during felling by approximately one-half and thus is a useful silvicultural tool. One-half of the climber stems not cut prior to logging survived felling of their host trees and sprouted vigorously. More than one-half of the climbers on infested trees several years after logging sprouted from fallen climbers.

Appanah, S. & J.M. Turnball.1998. A review of dipterocarps, taxonomy, ecology and silviculture. CIFOR, Bogor, Indonesia.

Applegate, G., K. Kartawinata, A. Machfudh & A. Klassen. 2001. Reduced impact logging guidelines for Indonesia. CIFOR Bogor, Indonesia.

Applegate, G., F.E. Putz, L.K. Snook. 2004. Who pays for and who benefits from the improved timber harvesting practices in the tropics? Lessons learned and information gaps. CIFOR, Bogor, Indonesia.

Arrigo-Nelson, S.J. & P.C. Wright. 2004. Differential fruit consumption in the rainforest: The impact of selective logging on food selection by *Propithecus diadema edwardsi* in Ranomafana National Park, Madagascar. Folia Primatologica 75: 404

Armesto, J. J., J. D. Mitchell & C. Villagran. 1986. A comparison of spatial patterns of trees in some tropical and temperate forests. Biotropica 18: 1-11.

Clumped spatial patterns predominant in all of a range of forests. Uniform patterns are rare in all forests. Forests with frequent catastrophes should exhibit mainly random patterns; clumping is more common where canopy gaps are the main agent of change.

Arnhem, E., J. Dupain, R.V. Drubbel, C. Devos, & M. Vercauteren. 2008. Selective logging, habitat quality and home range use by sympatric gorillas and chimpanzees: A case study from an active logging concession in Southeast Cameroon. Folia Primatologica 79: 1-14

Arnhem, E., J. Dupain, L. Van Elsacker, & M. Vercauteren. 2005. Effect of human activities on spatial distribution of gorillas (*Gorilla gorilla*) and chimpanzees (*Pan troglodytes*) in a logging concession in South East Cameroon: Preliminary results. Folia Primatologica 76: 46-47

Arroyo-Mora, J. P., M. Kalacska, R.L. Chazdon, D.L. Civco, G. Obando-Vargas, & A.A.S. Hernandez. 2008. Assessing recovery following selective logging of lowland tropical forests based on hyperspectral imagery. Pp 193-212 in Kalacska, M. & G.A. Sanchez-Azofeifa (eds.) Hyperspectral Remote Sensing of Tropical and Sub-Tropical Forests CRC Press Florida. 352pp

"The book explores a range of analysis techniques, including hyperspectral reflectance indices, spectral mixture analysis, pattern classification, band selection, partial least-squares, linear discriminant analysis, and radiative transfer models. The chapter authors present a comprehensive review of the current status and innovative achievements in the field, citing approximately six hundred studies." (Amazon.com, 2011)

Asabere, P. K. 1987. Attempts at sustained yield management in the tropical high forests of Ghana. in Mergen, F. & J.R. Vincent (eds.). Natural Management of Tropical Moist Forests: Silvicultural and Management Prospects of Sustained Utilisation. Yale University Press

Asdak, C., P.G. Jarvis, P. van Gardingen, & A. Fraser. 1998. Rainfall interception loss in unlogged and logged forest areas of Central Kalimantan, Indonesia. Journal of Hydrology 206: 237-244

Over a 6-month-period in 1 hectare of pristine, unlogged, natural, tropical rainforest, the total amount of rainfall interception loss was 251 mm or about 11% of total gross rainfall. In the logged forest, the total rainfall interception loss over 12 months was 219 mm, or 6% of gross rainfall.

Ashton, M.S. & C.M. Peters. 1999. Even-aged silviculture in tropical rainforests of Asia. Journal of Forestry 97: 14-19

Ashton, P. S. 1978. Crown characteristics of tropical trees. Pp 591-615 in Tomlinson & Zimmerman (eds.)

Ashton, P.S. (1988) Conservation of genetic resources. In: The Case for Multiple-Use Management of Tropical Hardwood Forests. Study produced for the International Tropical Timber Organisation. ITTO, Yokohama (Japan).

Asibey, E.O.A. 1978. Primate conservation in Ghana. Pp 55-59, in Chivers, D. J. & W. Lane-Petter (eds.) Recent advances in primatology, Vol. 2. London: Academic Press.

Asner, G.P., M. Keller, R. Pereira, J.C. Zweede, & J.N.M. Silva. 2004. Canopy damage and recovery after selective logging in Amazonia: Field and satellite studies. Ecological Applications 14: 280-298

Detailed field study of canopy gap analyses, combined with spectral mixture analyses of Landsat 7 ETM+ satellite Imagery. Forest canopy cover fractions derived from the satellite observations were highly and inversely correlated with the field-based canopy gap fraction. Areas used to stage harvested logs prior to transport had the largest forest gap fractions, but contributed little to landscape level gap dynamics. Tree falls were spatially the most extensive form of canopy damage, but the canopy gap fractions resulting from them were small. RIL resulted in consistently less damage to the forest canopy cf. conventional logging; this was true at scales from roads, skids and tree falls up to the area-integrated scale. A regional-scale study of the gap fraction using both the field and satellite-based measurements showed that approx. one half of the canopy opening caused by logging had closed within one year of regrowth.

Asner, G.P., M. Keller, & J.N.M. Silva. 2004. Spatial and temporal dynamics of forest canopy gaps following selective logging in the eastern Amazon. Global Change Biology 10: 765-783

Asner, GP; Powell, GVN; Mascaro, J; Knapp, DE; Clark, JK; Jacobson, J; Kennedy-Bowdoin, T; Balaji, A; Paez-Acosta, G; Victoria, E; Secada, L; Valqui, M; Hughes, RF. 2010. High-resolution forest carbon stocks and emissions in the Amazon. Proceedings of the National Academy of Sciences in the United States of America 107: 16738-16742

Assmann, E. 1970. The principles of forest yield study. 1st edn. Pergamon Press, Oxford.

Attiwill, P.M. 1994. The disturbance of forest ecosystems – the ecological basis for conservative management. Forest Ecology and Management 63: 247-300

Aubreville, A. 1938. La Forest coloniale. Annales Academie des Sciences Coloniales 9: 1-245

Augenfeld, K.H., S.B. Franklin, & D.H. Snyder. 2008. Breeding bird communities of upland hardwood forest 12 years after shelterwood logging. Forest Ecology and Management. 255 :1271-1282

Augeri, D. 2004. Disturbance effects on sun bears and their primary competitors in Indonesia. Presented at International Conference on Conservation Science Cambridge UK

Augspurger, C. K. 1983a. Offspring recruitment around tropical trees: changes in cohort distance with time. Oikos 40: 189-196.

Platypodium elegans (legume): for isolated trees, fungus-caused mortality nr. tree caused median distance of surviving 3 month old seedlings greater than that of germinating trees. After one year, the median either increased further, or decreased depending on availability of gaps which enhanced survival. Observed shift implies density or distance dependent mortality.

Augspurger, C. K. , 1983b. Seed dispersal of the tropical tree, *Platypodium elegans*, and the escape of its seedlings from fungal pathogens. Journal of Ecology 71: 759-771

Patterns of survival related to distance from parent, density of seedlings and the effect of a light gap. Most mortality occurred in first 3 months, caused by fungi, inversely correlated with distance from parents. Less died in light gaps. After 1 year, higher % and absolute number survived further from parent, especially in gaps. Greatest distance measured 100m.

Augspurger, C. K. 1984. Seedling survival of tropical tree species: interactions of dispersal distance, light gaps and pathogens. Ecology 65: 1705-1712.

Test of hypothesis in Barro Colorado Island, Panama, that seed dispersal enhances survival by escape from density-dependent mortality or colonisation of light gaps. 9 wind-dispersed trees were compared. Wind dispersal advantageous to all for different reasons. All 9 gained from colonisation. At some time over 1 yr all trees gained from 'escape' though differences occurred in distance and timing at which gains were made. Pathogens killed most shaded seedlings in 6/9 species.

Augspurger, C. K. 1986. Morphology and dispersal potential of wind-dispersed diaspores of neotropical trees. American Journal of Botany 73: 353-363.

Augspurger, C. K. & C. K. Kelly. 1984. Pathogen mortality of tropical tree seedlings: experimental studies of the effects of dispersal distance, seedling density and light conditions. Oecologia 61: 211-217.

Augspurger, C. K. & K. Kitajima. 1992. Experimental studies of seedling recruitment from contrasting seed distributions. Ecology 73: 1270-1284.

Augspurger, C. K. & K. P. Hogan. 1983. Wind dispersal of fruits with variable seed number in a tropical tree (*Lonchocarpus pentaphyllus*: Leguminosae). American Journal of Botany 70:1031-1037.

Augspurger, C. K. & S. E. Franson. 1987. Wind dispersal of artificial fruits varying in mass, area and morphology. Ecology 70: 27-34.

Models of 15 types of fruits were dropped from a 40 ft tower under 5 different wind conditions. The horizontal distance travelled is proportional to wind speed divided by square root of wing loading. Wing loading = force of gravity on fruit x projected surface area. The distribution of distance travelled results a left-skewed curve.

Auzel, P. & D.S. Wilkie. 2000. Wildlife use in northern Congo: Hunting in a commercial logging concession Pp 413-426 in Robinson, J.G. & E.L. Bennett (eds.) Hunting for sustainability in tropical forest. Columbia University Press. New York USA

Ayres, J. M. & A.D. Johns. 1987. Conservation of white uacaries in Amazonian várzea. Oryx 21: 74-80.

Azevedo-Ramos, C., O. de Carvalho, & B.D. do Amaral. 2006. Short-term effects of reduced-impact logging on eastern Amazon fauna. Forest Ecology and Management 232: 26-35

Azevedo-Ramos, C., J. R. Oswaldo de Carvalho, Robert, N. 2005. Animal Indicators, a Tool to Assess Biotic Integrity After Logging Tropical Forests? CIFOR.

Azlan J.M. 2003. The Diversity and conservation of mustelids, viverrids and herpestids in a disturbed forest in Peninsular Malaysia. Small Carnivore Conservation 29: 8-9

Babaasa, D., G. Eilu, A. Kasangaki, R. Bitariho, & A. McNeilage. 2004. Gap characteristics and regeneration in Bwindi Impenetrable National Park, Uganda. African Journal of Ecology 42: 217-224

Mean gap sizes are very large (4460.1m2) even under fairly natural conditions, and logging further enlarges these gap sizes. This has a negative impact on tree regeneration and promotes an alternative successional pathway, where the large gaps become dominated by herbs, shrubs and herbaceous or semi-woody climbers (low-canopy state).

Baharuddin, K. , A. M. Mokhtaruddin & M. Nik Muhamad. 1995. Surface runoff and soil loss from a skid trail and a logging road in a tropical forest. Journal of Tropical Forest Science 7: 558-569.

Soil runoff and loss measured using erosion plots from an undisturbed forest, a skid trail and a logging road. Two year study showed 62.9, 391.4 and 545.2 mm/yr respectively (2. 3%, 14. 5% and 20. 3% of the total rainfall). In year 2 losses decreased by 80%, probably due to reestablishment of ground cover. Increases also with slope. e. g. skid trail with a 20, 30, 40% slope had 314, 463, 630 mm surface runoff.

Baidoe, J. F. 1970. The selection system as practised in Ghana. Commonwealth Forestry Review 49: 159-165.

Baidoe, J. F. 1976. Yield regulation in the high forest of Ghana. Ghana Forestry Journal 2: 22-27.

Baker, P. 1998. Stem and crown relations in four species from an evermoist forest in Sri Lanka. Journal of Sustainable Forestry 7: 77-94

Tree crown represents the accumulated historic influences. *Macaranga peltata, Schumacheria castaneifolia, Shorea megistophylla, S. trapezifolia.* Species commonly associated with skid trails. 314 trees with no injury or vines, single-stemmed, not leaning, > 2m tall. All about 15 years old. Results: Crown volume= kR^2Z, where k=. 333 for cone and . 5 for paraboloid – latter favoured. Dbh & ht well correlated (r^2=0. 728 -. 667) for *Shorea spp.* which also had a steeper slope; Macaranga poorly correlated (r^2=. 211).

Bakuneeta, C. , K. Johnson, R. Plumptre & V. Reynolds. 1995. Human uses of tree species whose seeds are dispersed by chimpanzees in the Budongo forest. African Journal of Ecology 33: 276-278.

Confirms Chapman & Chapman (1994)'s observation made for Kibale forest that Chimpanzees are important dispersal agents for timber and other useful trees.

Baldwin, V. C. & K. D. Peterson. 1997. Predicting the crown shape of loblolly pine trees. Canadian Journal of Forest Research 27: 102-107

Banes, G.L. 2009.The Effects of Forest Disturbance on the Population Density of the Bornean Orang-Utan in Tanjung Puting National Park, Central Kalimantan, Indonesia. Folia Primatologica 80: 110-110

Barlow, J., C.A. Peres, L.M.P. Henriques, P.C. Stouffer, & J.M. Wunderle. 2006. The responses of Understory birds to forest fragmentation, logging and wildfires: An Amazonian synthesis. Biological Conservation 128:182-192

Barnard, R. C. 1956. Recruitment, survival and growth of tropical timber-tree seedlings in natural tropical rain forest. The Malayan Forester 19: 156-161.

Barrett, E.B.M. 1984. The ecology of some nocturnal mammals in the rain forest of peninsular Malaysia. PhD thesis, University of Cambridge

Basset, Y., E. Charles, D.S. Hammond, & V.K. Brown. 2001. Short-term effects of canopy openness on insect herbivores in a rain forest in Guyana. Journal of Applied Ecology 38: 1045-1058

Basset, Y., O. Missa, A. Alonso, S.E. Miller, G. Curletti, M. De Meyer, C.D. Eardley, M.W. Mansell, V. Novotny, & T. Wagner, 2008. Faunal turnover of arthropod assemblages along a wide gradient of disturbance in Gabon. African Entomology 16: 47-59

Baur, G. N. 1968. The ecological basis of rain forest management. Forestry Commission of New South Wales.

Baur, K. S. & M. Hadley (eds.). 1990. Reproductive ecology of tropical forest plants. Man and the Biosphere series. UNESCO, Paris.

Bawa, K. S. & P. A. Opler. 1975. Dioecism in tropical forest trees. Evolution 29: 167-179.

Bawa, K.S. & R. Seidler. 1998. Natural forest management and conservation of biodiversity in tropical forests. Conservation Biology 12: 46-55

Bazzaz, F. A. & S.T.A. Pickett. 1980. Physiological ecology of tropical succession: A comparative review. Annual Review of Ecology and Systematics 11: 287-310.

Bazzaz, F. A. 1991. Regeneration of tropical forests: physiological responses of pioneer and secondary species. Pp 91-118. in Gomez-Pompa, A., T.C. Whitmore and M. Hadley, (eds.). In Rain forest regeneration and management. Man and the biosphere series, Vol. 6. UNESCO Paris.

Useful overview of and references for physiological aspects of .

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Bearer, S., M. Linderman, J.Y. Huang, L. An, G.M. He, & J.Q Liu. 2008. Effects of fuelwood collection and timber harvesting on giant panda habitat use Biological Conservation 141: 385-393

Becker, P. & M. Wong. 1985. Seed dispersal, seed predation, and juvenile mortality of *Aglaia* sp. (Meliaceae) in lowland dipterocarp rainforest. *Biotropica* 17: 230-237

Beehler, B. M., K.S.R. Krishna, & S. Ali. 1987. Avian use of man-disturbed forest habitats in the Eastern Ghats, India. Ibis 129: 197-211.

Beer, T. & M. D. Swaine. 1977. On the theory of explosively dispersed seeds. New Phytologist 78: 681-694.

Beier, P. & R.F. Noss. 1998. Do habitat corridors provide connectivity? Conservation Biology 12: 1241-1252

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Line intersect (transect) method used to estimate residual log volume is biased if logs are not randomly directed, recommend use fan, triangle or L arrangement of transects.

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Impact of logging on virgin forest on East Kalimantan. Reviews different methods and intensities of exploitation in order to reduce logging damage and impact. Reduced impact logging promotes damage reduction and better utilisation. Damage assessed by three methods - area, trees>10 cm dbh, or sapling. 30% threshold recommended, and possible with RIL. Should be possible to reduce damage of trees to 25%. Used 12 plots (4 ha) in three blocks, with logging treatments. All trees ≥10 cm dbh enumerated (530/ha. SD 63; BA=31. 4, SD 3. 2). The 4 treatments were. Min. dbh 50 cm; climber cutting 3 months before felling; skidtrail planning;

1. Directional felling
2. As 1, but min. dbh 60 cm
3. 'Conventional logging'
4. Control, no logging.

On average, logging damaged c. 40% of trees; injured av. 21%; mortality (no resprout after 3 months) av. 19%, but slight decline with treatment 3->1->2. Felling mainly caused injuries; skidding caused most deaths. Injury (% original po.) peaks in the size class 40-50 cm; death % highest in smallest size classes (22%), only 7 of trees >60cm dbh. Controlled logging reduced skidding damage; but not felling damage, due to poor success of directional felling. Area disturbed was similar (12-16%) for <10 trees/ha. For heavily logged plots (15/ha.) damage control reduced area damage from 42% to 28%; sapling injury and mortality from 48% to 30%.

Bertault, J. G. & P. Sist. 1997. An experimental comparison of different harvesting intensities with reduced impact and conventional logging in East Kalimantan, Indonesia. Forest Ecology and Management 94: 209-218.

Conventional compared with reduced impact logging (RIL) using pre- and post-harvesting inventories for volume extracted and damage. Damage classes: bark and wood damage; leaning (0-25, 25-45, >45 degrees); slight to moderate crown injury (<5 main branches broken); Major crown injury (>5); broken trunk, still alive; broken trunk, dead; uprooted.

1000 ha. zone had a 5% pre-inventory. Twelve 200 x 200m plots, each divided into 4, were set up. Trees>10cm dbh were measured, numbered, mapped. Harvesting of dipterocarp trees>60cm dbh. 12 plots grouped into 3 blocks on topography and tree density. Four treatments defined and replicated three times. Treatments were two RIL (>50, >60); conv. and unlogged. RIL included tree marking, liane cutting; main skidtrail network pr-established according to topography. Directional felling; no roads in plot. Original Density 530 +- 63. 3 stems/ha; BA 31. 4+-3. 2 m2/ha. Dipterocarps had half the BA. Harvest ranged from 5 stems/ha to 15 stems/ha (43 to 174 m3/ha or 9. 8 to 30 m2/ha). Felling mainly injured trees (especially crown damage to trees 30-50 cm dbh), whereas skidding was main cause of mortality (especially uprooting and to trees 10-20 cm dbh). Results: A higher % of damaged trees in the middle size classes. 74. 5% of trees killed were 10-20cm dbh, but this class only holds 63% of trees. RIL reduced damage or death to trees from 48.4% to 30.5% (i.e. extra 95 trees/ha >10 cm dbh remain undamaged). In Borneo damage often exceeds 50%, which is more than Africa or S. America.

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PSP programme, logging experiment and yield allocation methodology in Belize; 70 pp stand tables. Total % dead and damaged trees increased almost linearly with volume/ha removed across 6 sites (from 5m3/ha to 26m3/ha), corresponding to 4. 7% to 9. 8% of the initial basal area. The majority of trees felled were of similar, small (by Ghanaian standards) size (40-70 cm dbh). This probably contributed to low % damage (6-14%), along with the RIL techniques such as careful attention to direction of felling, skid trail planning, and that the areas had been logged before, so skid trails were reused.

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Bongers, F. & F. J. Sterck. 1997. Architecture and development of rainforest trees: responses to light variation. Pp 125-162 in Newbery *et al.*

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Plot data with 2 re-censuses over 17 years is used to assess recovery in forest compartments categorised as heavily, moderately, lightly or un-logged. Structural recovery (based on DBH increment and basal area) is estimated to take 112-95 years for heavily and moderately logged compartments. Species composition recovery (species richness, division into early-mid-late successional stage species) estimated to take even longer. Recovery rates estimated at 0.32m$_2$ ha$_{-1}$ y$_{-1}$ in a moderately logged compartment and 0.25m$_2$ ha$_{-1}$ y$_{-1}$ in heavily logged areas. Key food tree species for 5 primate species concluded that recovery times of frugivorous primate's forest habitats were 2.5 times slower when compared with folivorous primates (whose preferred species did best in lightly logged compartments). Bias is likely to occur within biomass estimates derived from single unreplicated plots.

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Brown, K. & F. Ekoko. 2001. Forest encounters: Synergy among agents of forest change in Southern Cameroon. Society & Natural Resources 14: 269-290

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Selectively logged tropical rainforest in Indonesian Borneo is shown to contain high tree species richness, despite severe structural damage. Plots logged 8 years before sampling contained fewer species of trees >20cm DBH than did similar-sized unlogged plots. However, in samples of the same numbers of trees (requiring a 50% larger area), logged forest contained as many tree species as unlogged forest.

Cannon, C. H. , D. R. Peart, M. Leighton, & K. Kartawinata. 1994. The structure of lowland forest after selective logging in West Kalimantan, Indonesia. Forest Ecology and management 67: 49-68.

Unlogged dipterocarp forest compared with logged. Harvest removed 43% of total basal area. Small patches (15%) of lowland and 85% of swamp forest escaped logging disturbance. The canopy of 76% of lowland forest was moderately to heavily disturbed, with 45% in open gap or pioneer vegetation. 16% of area was routing of various sorts. Basal area harvested and canopy disturbance asymptotic. Disturbance weighted by severity to give a disturbance index. Graph of dist index=1. 31 x BA^0. 29 noisy (r2=0. 7). Dipterocarp trees below harvestable size (50cm dbh) suffered high mortality. Sampling was on 200m transects, with stumps measured in 20m wide belts, and disturbance levels stratified. Plots (40x50m for trees>50cm dbh; 20x50m for trees 20-50 cm dbh) were stratified-randomly placed in transects to measure living trees. Logging increased mortality in 20-35 cm dbh. Mean length of open gap segments decreases from c. 29 m 6 months after logging to 25m 1 yr after logging to 10m 8 years after logging.

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Brief report on two experiments on response of stand to pre-logging treatments and operational planning. In Sabah, diptercarp forest.

Expt. 1: long term effects of 4 modes of selective harvesting are evaluated in permanent plots (unsupervised; unsupervised with pre-felling climber cutting, directional felling and pre-marked skid trails; no logging). 20 treatments plots of 5.76 ha. each, 4 plots/treatment. 1 ha. inside the plots were pre-enumerated. The entire commercial crop was logged. Results not reported.

Expt. 2: Concerns felling only, with climber cutting and directional felling. Gap sizes, damage levels, felling accuracy were estimated. The study comprises 88 trees surrounded by a sampled local stand of 14 x 140m. 39% of trees felled within 5 degrees of desired angle; 24% within 6-10 degrees. Climber cutting didn't improve accuracy, but tree heart rot and slopes made it worse.

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Chai, D.N.P., & M.P. Udarbe. 1977. The effectiveness of current silvicultural practice in Sabah. Malaysian Forester 40: 27-35.

Chambers, J.Q., N. Higuchi, L.M. Teixeira, J. dos Santos, S.G. Laurance, & S.E. Trumbore. 2004. Response of tree biomass and wood litter to disturbance in a Central Amazon forest. Oecologia 141: 596-611

Chandrashekara, U.M. & K.A. Sreejith. 2006. Assessing recovery of humid tropical forests after selective logging in the Western Ghats of Kerala, India. Current Science 91: 421-423

Around 50 years is the estimated time required for selectively logged forests to recover to resemble undisturbed forests in terms of seedling and tree density and basal area distribution.

Chapman, C.A., S.R. Balcomb, T.R. Gillespie, J.P. Skorupa, & T.T. Struhsaker. 2000. Long-term effects of logging on African primate communities: a 28-year comparison from Kibale National Park, Uganda. Conservation Biology 14: 207-217

Chapman, C. A. & L. J. Chapman. 1997 . Forest regeneration in logged and unlogged areas of the Kibale National Park, Uganda. Biotropica 29: 396-412

Forest logged 30 years ago barely regenerates, except for *Acanthus*. Few trees.

Chapman, C.A. & L.J. Chapman. 2004. Unfavourable successional pathways and the conservation value of logged tropical forest. Biological Conservation 13: 2089-2105

Chapman, C. A. , L. J. Chapman, R. Wranham, C. Isabirye-Basuta & K. Ben-David. 1997. Spatial and temporal variability in the structure of a tropical forest. African Journal of Ecology 35: 287-302.

Kibale, Uganda. 4 areas separated by < 15km differ in phenology & species composition. Marked changes in tree densities since 1970s.

Chapman, C. A. , L. J. Chapman, L. Kaufman & A. E. Zanne. Potential causes of arrested succession in Kibale National Park, Uganda: growth and mortality of seedlings. African Journal of Ecology 37: 81-92.

Kibale, lack of recovery 30 years after logging hypothesised to be due to lack of aggressive tree species. Trial planting of a few species in gaps –e. g *Cynometra, Celtis, Funtumia, Teclea.* Concludes that few species perform better in gaps than non-gaps.

Chapman, C. A. , L. J. Chapman, R. W. Wrangham, K. Hunt, D. Gebo & L. Gardner. 1992. Estimators of fruit abundance of tropical trees. Biotropica 24: 527-531.

Dbh linearly related to the mass of fruit produced for many species.

Chapman, C.A. & J.E. Lambert. 2000. Habitat alteration and the conservation of African primates: Case study of Kibale National Park, Uganda. American Journal of Primatology 50: 169-185

Chapman, C. A. , R. W. Wrangham, L. J. Chapman, D. K. Kennard & A. E. Zanne. 1999. Fruit and flower phenology at two sites in Kibale National park, Uganda

104 species (3793 trees) monitored monthly over 76 months at two sites 10km apart. Spectral analysis for patterns and graphical methods for abundance. At one site, flowering and fruiting had regular annual peaks, with fruiting negatively related to min. temperature in the previous 3-7

month season, peaking towards the start of the dry season, but at the other site fruiting was more irregular with no annual peaks. Fruiting synchronous for 64% of species.

Chapman, C.A., Struhsaker, T.T., Skorupa, J.P., Snaith, T.V., Rothman, J.M., 2010a. Understanding long-term primate community dynamics: implications of forest change. Ecological Applications 20: 179–191

Chapman, C.A., Chapman, L.J., Jacob, A.L., Rothman, J.M., Omeja, P., Reyna-Hurtado, R., Hartter, J., Lawes, M.J., 2010b. Tropical tree community shifts: implications for wildlife conservation. Biological Conservation 143: 366–374

Chazdon, R.L., 2003. Tropical forest recovery: legacies of human impact and natural disturbances. Perspectives in Plant Ecology, Evolution and Systematics 6: 51–71

Review covering the recovery of forest following various impacts, including logging.

Chazdon, R. And Fetcher, N. 1984. Photosynthetic light environments in a lowland tropical rain forest in Costa Rica. *Journal of Ecology* 72:553-564.

Chazdon, R.L., Letcher, S.G., Van Breugel, M., Martínez-Ramos, M., Bongers, F., Finegan, B., 2007. Rates of change in tree communities of secondary neotropical forests following major disturbances. Philosophical Transactions of the Royal Society B 362: 273–289

Review focusing on vegetation change following abandonment of agricultural fields. Rates of change in tree communities following major disturbances are determined by a complex set of interactions between local site factors, landscape history and structure, regional species pools and species life histories. Recovery of five tree community attributes are considered: stem density, basal area, species density, species richness and species composition. Structural recovery thought to be the most predictable over time.

Cheke, A. S. , W. Nanakorn, C. Yankoses. 1979. Dormancy and dispersal of secondary forest species under the canopy of a primary tropical rain forest in northern Thailand. Biotropica 11: 88-95

Chim, L. T. & W. F. On. 1973. Density, recruitment, mortality and growth of Dipterocarp seedlings in virgin and logged-over forests in Sabah. The Malaysian Forester 36: 3-15.

Seedling density varies from one locality to another, and after a heavy seedfall many seedlings are found around parents of which only a few (0. 8%-17%) survive into the 'regeneration pool'. Mortality in the regeneration pool is continuous but increases after logging. Only 14% of seedlings survived three years. 98% seedlings responded to light liberation treatment, but larger seedling responded more vigorously.

Chua, S.L., W.D. Hawthorne, L.G. Saw & E. S. Quah. 1998. Biodiversity database and assessment of logging impacts. pp. 30-41, in Lee, S.S., S.S. Lee, Dan Y.M., Gauld, I.D. & J.Bishop (eds.), 1998. Conservation, management and development of forest resources.

CIFOR. 2004. Workshop to develop a regional applied research program in the Congo Basin (ITTC Decision 10 (XXXII)): pilot study on the social, environmental and economic sustainability of industrial concessions in the Congo Basin, main reports, part D. International Tropical Timber Organisation, Tokyo, Japan.

Cintra, R. 1997. A test of the Janzen-Connell model with two common tree species in Amazonian forest. Journal of Tropical Ecology 13: 641-658

Emergent legume *Dipteryx micrantha* and midstorey palm *Astrocaryum murumuru*. *Dipteryx* survival increased with distance from conspecific adults within 100 ha. *Astrocaryum* predation density dependent within 2.5ha plot. At 200-400ha scale seed survival negatively related to density of adults, although varied with time.

Claridge, A., A. McNee, M.T.Tanton, & S.M. Davey. 1991. Ecology of bandicoots in undisturbed forest adjacent to recently felled logging coupes: a case study from the Eden Woodchip Agreement Area. Pp 331-346 in Lunney, D. (ed.) Conservation of Australia's forest fauna. Mosman: Royal Zoological Society of New South Wales.

Clark, C.J., J.R. Poulsen, R. Malonga, & P.W. Elkan. 2009. Logging concessions can extend the conservation estate for Central African Tropical Forests. Conservation Biology 23:1281-1293

Considers the impact of logging on large mammal populations.

Clark, D. A. & D. B. Clark. 1984. Spacing dynamics of a tropical forest tree: evaluation of the Janzen-Connell model. American Naturalist 124: 768-788.

Clark, D. A. & D. B. Clark. 1991. The impact of physical damage on canopy tree regeneration in tropical rain forest. Journal of Ecology 79: 447-457.

The frequency, rates of occurrence, and consequences of physical damage to individuals of nine canopy tree species in primary tropical rain forest at the La Selva Biological Station, Costa Rica are investigated. Frequency of damage varied from 9 to 27% among five size classes and was negatively correlated with diameter growth rates for stems 1-30 cm in diameter. Rates of damage due to falling litter ranged from 1 to 7% per year for trees up to 30 cm in diameter. Calculated half-lives until death or damage due to falling litter increased from 10 years for stems less-than-or-equal-to 1 cm in diameter to 63 years for stems 10-30 cm in diameter. Rates of mortality were higher in damaged individuals than in undamaged plants for stems up to 10 cm in diameter. Absolute rates of mortality decreased with increasing stem diameter, but the relative contribution of physical damage as an agent of mortality increased with stem diameter. Litterfall caused at least 20% of the mortality of stems less-than-or-equal-to 1 cm in diameter, and accounted for 41% of the deaths of stems 1-30 cm in diameter.

Clark, D. A. & D. B. Clark. 1992. Life history diversity of canopy and emergent trees in a neotropical rain forest. Ecological Monographs 62: 315-344.

6 year monitoring 150ha for survival, growth, microsite of 6 non-pioneers in Costa Rica (Lecythis ampla, Hymenolobium mesoamericanum, Dipteryx panamensis, Pithecellobium elegans, Hyeronima alchorneoides, Minquartia guianensis – the first 5 being emergents; 2 pioneers Cecropia insignis, C. obtusifolia and high-light demander Simaruba amara.). Assessed num. overtopping crowns, gap phase, crown illumination index (1 to 5 =no direct light to completely exposed). For first six, mortality declined and increment increased with size. Four patterns defined in terms of change of microsite. 'For non-pioneer tropical trees, life history classificaion based on generalised concepts such as gap dependence and shade-tolerance is inadequate to describe the complex size-dependent patterns of life history differences and similarities that exist among species'.

Clark, D. B. & D. A. A. Clark. 1996. Abundance, growth and mortality of very large trees in neotropical lowland forest. Forest ecology and management 80: 235-244

Clark, S. C, M. Silman, R. Kern, E. Macklin & J. Hillerislambers. 1999. Seed dispersal near and far: patterns across temperate and tropical forests. Ecology 80: 1475-1494.

Near and long distance dispersal considered. Using a '2DT' model, less seed travels <5m from the crown and more travels long distances (>30m) than the standard Gaussian model.

Clarke, E. C. 1956. The regeneration of worked out Greenheart (*Ocotea rodiaei*) in British Guiana. Empire Forestry Review 35: 173-183.

Based on earlier experiments by Davis in greenheart forest in the Bartica triangle, ground fires are an effective method of improving growth of greenheart forest. Greenheart is shade tolerant for several years, but grow rapidly when overhead light is provided, and soon tolerate full light.

Clarke, F.M., D.V. Pio, & P.A. Pacey. 2005. A comparison of logging systems and bat diversity in the Neotropics. Conservation Biology 19:1194-1204

Claussen, J. W & C. R. Maycock. 1995. Stem allometry in a North Queensland tropical rain forest. Biotropica 4: 421-426.

Four species in Queensland, two early successional and two later successional. Stem allometry not different within 'guilds' but different between them. All trees have high buckling safety margin when small, but medium stature trees of late successional have low margin. Stem allometry may be influenced by life-span, wood density and environmental conditions in the crown.

Cleary, D.F.R. 2004. Assessing the use of butterflies as indicators of logging in Borneo at three taxonomic levels. Journal of Economic Entomology 97:429-435

Cleary, D.F.R., T.J.B. Boyle, T. Setyawati, C.D. Anggraeni, E.E. Van Loon, & S.B.J. Menken. 2008. Bird species and traits associated with logged and unlogged forest in Borneo. Ecological Research 17:1184-1197

Cleary, D.F.R. & A.O. Mooers. 2006. Burning and logging differentially affect endemic vs. widely distributed butterfly species in Borneo. Diversity and Distribution 12:409-416

Clinnick, P.F. 1985. Buffer strip management in forest operations: a review. Australian Forestry 48: 43-45.

Clubbe, C. P. & S. Jhilmit. 1992. A case study of natural forest management in Trinidad. Pp. 201-209 in Miller F. R. & K. L. Adam, (eds.) Wise management of tropical forests: Oxford Forestry Institute.

Cobbinah, J.R. 1997. Major insect pests of humid Africa and their management. Paper submitted to the XI World Forestry Congress, Antalya, Turkey.

Cockle, KL; Martin, K; Drever, MC. 2010. Supply of tree-holes limits nest density of cavity-nesting birds in primary and logged subtropical Atlantic forest. Biological Conservation 143: 2851-2857

Colchester, M. 2000. High conservation value forests, note A. Proposed elements of a new forest policy. 3rd input to the safeguards and definitions focus group of the technical advisory group. Forest Peoples Programme. The World Bank, Washington, USA

Collins, N. M. 1980. The effect of logging on termite (Isoptera) diversity and decomposition processes in lowland dipterocarp forests. Pp 113-121 in Furtado, I. (ed.) Tropical ecology and development, Vol. 1 Kuala Lumpur: International Society of Tropical Ecology.

Colón, C.P. 1999. Ecology of the Malay Civet (*Viverra tangalunga*) in a logged and unlogged forest in Sabah, in East Malaysia. PhD dissertation Fordham University New York USA.

Congdon, R. A. & J. L. Herbohn. 1993. Ecosystem dynamics of disturbed and undisturbed rainforests in north Queensland wet tropical rain forest. 1. Floristic composition, climate and soil chemistry. Journal of Tropical Ecology 9: 349-363

Connell, J. H. 1971. On the role of natural predators in preventing competitive exclusion in some marine animals and in rain forest trees. Pp 298-310 in den Boer, P. J. & G. R. Gradwell (eds.) Dynamics of populations. Centre for Agricultural Publications and Documentation. Wageningen. The Netherlands

Connell, J.H. 1979. Tropical rain forests and coral reefs as open non-equilibrium systems. In: *Population Dynamics*. Anderson, R.M., Turner, B.D., Taylor, L.R. (eds.). Blackwell Scientific Publications, Oxford, U.K.

Connell, J. H. , J. G. Tracey & L. J. Webb. 1984. Compensatory recruitment, growth and mortality as factors maintaining same forest tree diversity. Ecological Monographs 54: 141-164.

Two hypotheses concerned with maintenance of rarer species in rain forest tested in tropical evrgreen rain forests in Australia. Hypothesis 1. at 1-2 ha. scale, commoner species have lower rates of recruitment than rarer. Hypothesis rejected for growth and mortality and for recruitment of overstorey spp, but not rejected for recruitment in canopy and Understory spp. Hypothesis 2. Close proximnity is more deleterious (slower growth or higher mortality) if they are the same species. Accepted for growth or survival in several of the seedling size classes. However, increased densities of the same species had no more deleterious effect than other spp.

90% of species tested showed no pattern of mortality of seedlings or saplings nearer conspecific adults.

Coombe, D. E. 1960. An analysis of the growth of *Trema guineensis*. Journal of Ecology 45: 823-830.

Coombe, D. E. & W. Hadfield. 1962. An analysis of the growth of *Musanga cercropioides*. Journal of Ecology 50: 221-230.

Cooper, R.G 1979. The dimensions of industrial new product success and failure. *Journal of Marketing* 43:93-103.

Cooper, St. G. C., P.R. Bacon, W.S. Chalmers & J.S. Kenny (eds.) 1981. The natural resources of Trinidad and Tobago. London: Edward Arnold.

Corbasson, M. & O. Souvannavong. 1988. *Terminalia superba* Engl. & Diels: current research on biology, physiology and breeding of *Terminalia superba*. Informations sur les Ressources Genetiques Forestieres (FAO)16: 29-34.

Costa Filho, P. P. 1991. Mechanised logging and the damages caused to tropical forests: case of the Brazilian Amanzon. Actes du Xe Congres forestier mondial. Paris 17-26 Sept. 1991.

Costa, F. & W. Magnusson. 2002. Selective logging effects on abundance, diversity, and composition of tropical Understory herbs. Ecological Applications 12:807-819

Found herb community composition not to be significantly correlated with logging intensity, and no significant difference in community composition and richness between treatments with different times after logging. Some species (18.2%) were found only in logged plots and were mainly from habitats outside the rain forest. There were significant differences in herb composition between controls and skid trails, but recent and old skid trails were mixed in the ordination space, suggesting that recovery in skid trails is slower than in other areas affected by logging.

Cowley, R. D. 1971. Birds and forest management. Australian Forestry 35: 234-250.

Crome, F. H. J. & L.A. More. 1989. Display site constancy of bowerbirds and the effects of logging on Mt Windsor tableland, north Queensland. Emu 89: 47-52

Crooks, K.R. 2002. Relative sensitivities of mammalian carnivores to habitat fragmentation Conservation Biology 16:488-502

Crome, F. H. J. , L. A. More & G.C. Richards. 1992. A study of logging damage in upland rainforest in north Queensland. Forest Ecology and management 49: 1-19.

19ha plot of upland rainforest logged under Queensland Selective logging system. Logged trees mainly on ridges c. 6.6 stems, 4.9m^2 and 3.7m^3 logs removed per ha. Losses (147 stems/ha, 1m^2/ha) were highest in the smallest and largest size classes. 22% of canopy lost. Logging tracks on 5% of area. Includes a map of skidtrail network, and a summary graph relating incidental losses to number of trees harvested for 6 studies in Asia and S. America. A detailed map of, and canopy histograms showing, canopy loss are also shown. An appendix describes the Queensland logging system.

Crome, F.H. J, M.R. Thomas & L.A Moore. 1996. A Novel baysian approach to assessing impacts of rainforest logging. Ecological Applications 6: 1104-1123

Curran L.M., I Caniago, G.D. Paoli, D. Astianti, M. Kusenti, C.E. Nirarita, & H. Haeruman. 1999. Impact of El Nińo and logging on canopy tree recruitment in Borneo. Science 286: 2184-2188

Logging of dipterocarps reduced the extent and intensity of mast fruiting episodes and exacerbated local El Nino conditions. Viable seed and seedling establishment declined as a result of climate, logging, and predators. Since 1991, dipterocarps have experienced recruitment failure within a national park, now surrounded by logged forest.

Curtin, R. A. 1964. Stand density and the relationships of crown width to diameter and height in *Eucalyptus oliqua*. Australian Forestry 28: 91-105.

D'Olivera, M. V. N. & E. M. Braz. 1995. Reduction of damage to tropical moist forest through planned harvesting. Commonwealth Forestry Review 74: 208-210.

Damage during logging in Brazil assessed briefly. The main features of the approach to damage reduction were survey, care in road and skid construction, climber cutting and directional felling. The amount of damage was 5.3 greater than 10cms and vol was 0. 27m^3 per m^3 extracted for the 20m^3 /ha were harvested. Damage resulted in a max. canopy opening of 15%.

Da-Alencar, J. C. De-Almeida & N. P Fernandes 1979. Phenology of tree species in the terra firme tropical rain forest in central Amazonia. Acta Amazonica 9: 163-168

Dahaban, Z., M. Nordin & E.L. Bennett. 1996. Immediate effects on wildlife of selective logging in a hill dipterocarp forest in Sarawak: mammals. Monographiae Biologicae 74: 341-346

Dale, J. A. 1983. Management studies in the escarpment rainforests of South east Queensland Research Papers of the Department of Forestry, Queensland 14: 1-90.

Dale, S. & B. Slembe. 2005. Effects of selective logging (50 years ago) on habitat use and ranging behaviour of a forest Understory bird (red-tailed bristlebill, *Bleda syndactyla*) in Uganda. African Journal of Ecology 43:114-122

Dallmeier, F. & J. A. Comiskey. 1998. Forest biodiversity research, monitoring and modelling. Conceptual background and old world case studies. Man and the Biosphere series Vol. 20. UNESCO, Paris & Parthenon.

Damio, T., F. Doumbia, B. Dupuy, N. Higuchi, K. Kadir, H.F. Maitre, N. Nguyen-The., Y. Petrucci, & P. Sist. 1997. Forest stand reactions to silvicultural operations. Bois et Forets des Tropiques 0:5-24

Danielsen, F. 1995. Stable environments and fragile communities: Does history determine the resilience of avian rain-forest communities to habitat degradation? Biodiversity and Conservation 6: 423-433

Danielsen, F. & M. Heegaard. 1995. Impact of logging and plantation development on species diversity: a case study from Sumatra. Pp 73-92. in Sandbukt, O. (ed.) Management of tropical forests: towards an integrated perspective. Oslo, Norway: Centre for Development and the Environment, University of Oslo.

Danso, L. K. 1970. Seed production by *Triplochiton scleroxylon*. Tech. Newsletter. Forest Products Research Institute, Ghana 4: 21-22.

Datta, A. & S.P. Goyal.1996. Comparison of forest, structure and use by the Indian giant squirrel (*Ratufa indica*) in two riverine forests of central India. Biotropica 28: 394-399.

Datta, A. 1998. Hornbill Abundance in unlogged, selectively logged and a forest plantation in Arunchal Pradesh. India. Oryx 32: 285-294

Datta, A. 2000. Pheasant abundance in selectively logged and unlogged forests of western Arunachal Pradesh, north east India, Journal of Bombay Natural History Society 97:177-183

Davey, S. M. 1989. Thoughts towards a forest wildlife management strategy. Australian Forestry 52: 56-67

Davidson, J. 1983. Forestry in Papua New Guinea: a case study of the Gogol Woodchip Project near Madang. Pp 19-138 in Hamilton L.S (ed.) Forest and watershed development and conservation in Asia and the Pacific, Boulder, Colorado: Westview Press.

Davies, A. G. 1987. The Gola Forest Reserves, Sierra Leone: wildlife conservation and forest management. Gland, Switzerland: IUCN.

Davies, A.G. & J.B. Payne. 1982. A faunal survey of Sabah, Kuala Lumpur, Malaysia: WWF Malaysia.

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Davies, G. 1986. The orang-utan in Sabah. Oryx 20: 40-45

Davies, G, M. Heydon, N. Leader-Williams, J. MacKinnon, & H. Newing. 2001. The effects of logging on tropical forest ungulates in Fimbel, R.A., A. Grajal & J.G Robinson (eds.) The cutting edge: conserving wildlife in logged tropical forest. Columbia University Press New York USA

Davies, R.G., P. Eggleton, L. Dibog, J.H. Lawton, D.E. Bignell, A. Brauman, C. Hartmann, L. Nunes, J. Holt, & C. Rouland. 1999. Successional response of a tropical forest termite assemblage to experimental habitat perturbation. Journal of Applied Ecology 36: 946-962

Davis, A.J., J.D. Holloway, H. Huijbregts, J. Krikken, A.H. Kirk-Spriggs, &. S.L. Sutton. 2001. Dung beetles as indicators of change in the forests of northern Borneo. Journal of Applied Ecology 38: 593-616

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Davis. F.W., D.M. Stoms, J.E. Estes, & J. Scepan.1990. An information systems approach to the preservation of biological diversity. International Journal of Geographic Information. Systems 4: 55–78

Dawkins, H. C. 1956. Rapid detection of aberrant girth increment of rain-forest trees. Empire Forestry Review 35: 449-454.

Very detailed girth increment measurements establish that trees have irregular increment over a year, and can shrink or remain static for many months, although rainfall is a good predictor.

Dawkins, H. C. 1958a. Further measurements of felling damage in tropical High-forests. Technical note 6. Uganda Forest Department.

144 trees (5' (12.7cm) to 14' (35.6cm) dbh) felled in 33. 6 acres= 4.3 trees felled/acre; av. gap size=. 034/tree; other damage =. 028; total=. 062 acres per tree. Damage caused by 4.3 trees=26% of area. Loss among (pre & post-enumerated) juvenile trees = 25%. 2. 5 miles log tracks av. 13 ft wide. Damage per gap is lower (34%) in this pretreated forest than in an earlier study of untreated forest which had greater mass of climbers and 'Understory'. Also, smaller trees were felled in this study. Author suggests 0. 05 acres total devastation per tree is a reasonable average.

Dawkins, H. C. 1958b. The management of tropical high forest with special reference to Uganda. Imperial Forestry Institute Paper 34. IFI Oxford, UK.

Broad discussion of many aspects (inventory, silvicultural system, economics, stand curves etc.) of tropical forest management, and a foundation, or at least justification, for much that is still practiced. In effect a text book of tropical forest management for the 1960s, whose basic principles have yet to be adopted by a significant proportion of tropical forest managers. A few of the topics (e. g. the principle of concentrating on 'leading desirables' in certain forest assessments) have subsequently fallen into disfavour, however.

Dawkins, H. C. 1959. The volume increment of natural tropical high forest and limitations on its improvement. Empire Forestry Review 38: 175-180.

All species stand-table similar in different regions of tropical high forest (THF), where little disturbed. Typical values of Girth Class in ft: Stems per acre: 1:100, 2:41, 3:17, 4:8, 5:4. 5, 6:2. 9, 7:2, 8:1. 4, 9:1. 0, 10:0. 7, 11+:1. 5. Some Australasian forests have higher stocking of middle sizes, and sometimes even-aged. Basal area often around 140 sq. ft. /acre. (100-160). Hence, this is a limiting basal area: when reached no further increment can be expected. Plantations can attain half this. Strong correlation between crown size and girth increment for most species. e. g. a tree of 4ft girth will not grow well without crown of 40ft. Healthy 8ft gbh (244cm dbh) trees have crown diameter up to 60ft (18.3m). Hence, thinning to release older trees often has no effect: crown development should be encouraged early. Light rarely limiting for photosynthesis, problem is crown does not get bigger in the shade. Therefore, with 60ft crowns, max spacing of big trees is 14/acre. (40ft =31/acre: 50ft=20/acre). Healthy final crop of most trees therefore 20/acrea; although narrow crowned trees like *Lovoa* and *Celtis* could reach 30/acre. Most trees in THF slow growing: too crowded; crowns generally too small (unless developed in middle of large gap); Most shaded; senility/stagnation of large tree increment can last at least 20 years on healthy trees. Therefore 8ft gbh crops not possible in < 80 years, with these limitations. However, many pioneers can reach this size, if exposed.

The limits on polycyclic systems by felling damage Large crowns needed for fast growth. But large crowns cause more felling damage. In Uganda, 8-12 ft gbh trees devastates 0. 1 acre of forest, effectively resetting that area to zero. Without climbers this could be halved; perhaps reduced at most to 0.05 acre/tree. This limits polycyclic systems (where felling cycle rotation). No annual acre yields > 30 ft possible, because: Suppose that five 8ft trees are to be felled per acre every ten years. After four felling cycles (or 6 with greatest care) the entire area will have been felled over. Unless species average > 1 ft girth in 10 yrs when grown among bigger trees; or felling damage reduced to . 025 per mature tree felled, then max. yield of African THF is 20 ft3/acre.

Dawkins, H. C. 1963a. Crown diameters: their relation to bole diameter in tropical forest trees. Commonwealth Forestry Review 42: 318-333.

Seventeen tropical trees examined. Most practical relation is given as Diam=A-(B x dbh). A is related to tolerance: intolerant species have low a values (unaffected by treatments); tolerant species have variable a values, indicative of treatment. Even-aged crops have negative a values. The relationship of form to 'packing' is explored.

Dawkins, H. C. 1963b. Observations on crown-diameter, stocking, silvicultural requirements and possible yield of *Maesopsis*. Technical Note Forestry Dept. Uganda 114/6: 2.

Dawkins, H. C. 1963c. The productivity of tropical high forest trees and their reaction to the controllable environment. D. Phil. thesis. University of Oxford, UK.

Dawkins, H. C. and Field, D. R. 1977. A long-term surveillance system for British woodland vegetation. Oxford University, Dept. of Forestry. Occasional Paper No. 1. 106pp.

Dawkins, H. C. & M. S. Philip. 1998. Tropical Moist forest silviculture and management: a history of success and failure. CAB International. Wallingford, UK.

De Clerk, M. 1991. Regeneration strategies of some emergent tree species in Cote d'Ivoire. A. V. 91/29. Dept. of Forestry, Wageningen Agric. Univ.

De Freitas, J.V. & M.A. Pinard. 2008. Applying ecological knowledge to decisions about seed tree retention in selective logging in tropical forests. Forest Ecology and Management 256: 1434-1442

Study in Amazonas, Brazil. Seed trees were retained (not felled) as a proportion of harvestable trees, where the proportion was defined as a function of species' ecological attributes and local abundance (100 ha), in contrast to the conventional approach which retained 10% of harvestable trees, uniformly across commercial species at the compartmental scale (1000 ha). The conventional approach resulted in the retention of relatively high proportions of potential seed trees for common species (e.g., 22% for *Eperua oleifera* and 36% for *Maquira sclerophila*) that are shade bearers and recruit readily at the site; conversely, for species with constraints to regeneration, it retained relatively low proportions (e.g., 2% for *Dinizia excelsa* and *Hymenolobium nitidum*). The alternative approach effectively retained lower proportions of common species (e.g., 10% for *E. oleifera* and 13% for *M. sclerophila*) and relatively high proportions of species with regeneration constraints (e.g., 20% for *D. excelsa* and 16% for *H. nitidum*). The conventional approach failed to retain any seed trees at the 100 ha block scale for 7 of 37 commercial species, whereas the alternative approach retained a minimum number of seed trees per 100 ha block for all commercial species. Species-specific retention rules can be developed that take into account local abundance, when inventory data are digitised and spatially explicit.

De Graaf, N. R. 1986. A silvicultural system for natural regneration of tropical rain forest in Suriname. Wageningen Agricultural University, The Netherlands.

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20 m^3 timber every 20 years with three poisoning interventions, on very infertile soils. Projected all-species basal area increment is about 1 m2/year at first.

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Female individuals bear a few ripe fruits per day over 4-5 months; eaten by 28 vertebrate spp. but birds and bats probably most efficient. Recruitment 176/ha/yr on roadside, much less 0. 8/ha/yr in established populations. Few ripe fruits accumulate under parents, although more than 40% of juvenile plants are within 5 m of an adult. Likelihood of long distance dispersal is also mentioned.

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Forestry Department of Ghana. 1992b. Handbook of harvesting rules. Planning branch, Forestry, Ghana.

Forestry Department of Ghana. 1995. Manual of Procedures High Forest Management. Section D Stock survey and Yield Allocation. Planning branch, Forestry, Ghana. See also Ghana Forest Service.

This section of the manual of procedures, which exists in various version, is the main document describing the technical process of yield allocation and stock map production, for reference by loggers, checkers and yield allocators alike. The 6 sections describe: Presurvey compartment inspection; Stock Survey; Stock survey checks; stock map preparation; yield allocation and diameter measurement on buttressed trees, including details such as the symbols to use for each species of tree.

Forestry Department of Ghana – See also 'Ghana Forest Service' for 1998 onwards.

Forest Products Inspection Bureau (FPIB) 1991. Annual Report, FPIB, Takoradi.

Forget, P. M. 1989. Natural regeneration of an autochorous species in the forest of French Guiana: *Eperua falcata*. Biotropica 21: 115-125.

Seeds ejected during low humidity. c. 60% of seeds < 10m from parent; max dispersal 30m. Seeds slowly eaten by rodents, not distance dependent. Seedling mortality low; shade-tolerant, boosted greatly by gaps. Saplings found optimal distance is ½ way between two trees, outside crown limit.

Forget, P. M., F. Mercier & F. Collinet. 1999. Spatial patterns of two rodent-dispersed rain forest trees *Carapa procera* (Meliaceae) and *Vouacapoua americana* (Caesalpiniaceae) at Paracou, French Guiana.

Both species dispersed by rodents within range of 50m of adults, *V. americana* strongly aggregated but *Carapa* more random. Soils found to influence the patterns, which are described at different scales.

Forget, P.M., J.M. Rankin-De Merona, & C. Julliot. 2001. The effects of forest type, harvesting and stand refinement on early seedling recruitment in a tropical rain forest. Journal of Tropical Ecology 17:593-609

Forman, R.T.T. & L.E. Alexander. 1998. Roads and their major ecological effects Annual Review of Ecology & Systematics 29:207-231

Foster, R. B. 1982. The seasonal rhythm of fruit fall on Barro Colorado Island. Pp 151-172 in Leigh, E. G. , A. S. Rand, & D. M. Windsor (eds.) Smithsonian Institution Press. Washington D. C.

Fownes, J. H. & R. A. Harrington. 1990. Modelling growth and optimal rotations of tropical multipurpose trees using leaf rate and leaf area index. Journal of Applied Ecology 27: 886-896.

Fox, J. E. D. 1968a. Logging damage and the influence of climber cutting prior to logging in the lowland dipterocarp forests in Sabah. The Malayan Forester 31: 326-347.

27% of the area was covered by tractor tracks and 42% of the seedlings were destroyed. Climber cutting reduces damage.

Fox, J. E. D. 1968b. Defect, damage and wastage. The Malayan Forester 31: 326-347.

Damage to pole-sized trees caused by felling in climber infested areas halved by cutting the climbers two years before felling.

Fox, J. E. D. 1972. The natural vegetation of Sabah and natural regeneration of the dipterocarp forests. PhD thesis. Univ. College N. Wales, Bangor (As cited by Tang, 1976)

Mean mortality for trees>10 cm dbh =2. 3% was 7-8 years after logging and 2% over the first 12 years.

Fox, J. E. D. 1976. Constraints on natural regeneration of tropical moist forests. Forest Ecology and Management 1: 37-65.

Frankie, G. W. , H. G. Baker, & P. A. Opler. 1974. Comparative phenological studies of trees in tropical wet and dry forests in the lowlands of Costa Rica. Journal of Ecology 62: 881-919.

Fredricksen, N.J. & T. S Fredricksen. 2002. Terrestrial wildlife responses to logging and fire in a Bolivian tropical humid forest. Biodiversity and Conservation 11: 27-38

Fredericksen, N.J. & T.S. Fredericksen, 2004. Impacts of selective logging on amphibians in a Bolivian tropical humid forest. Forest Ecology and Management 191: 275-282

Frederiksen, T. S. 1998. Limitations to low-intensity selection and selective logging for sustainable tropical forestry. Commonwealth Forestry Review 77: 262-266

Selective, non-sustainable cleaning; this and Selection retain forest cover. Selective is more common. Many timber species require higher light levels than this (see Fox 1976) especially *Swietenia* and in dry forests. Height growth of commercial species in Bolivian semi-dry forest, shown to be better on logging roads and log landings than skid trails etc. Lianas best in felled tree gaps.

Fredericksen, T.S. & F.E. Putz. 2003. Silvicultural intensification for tropical forest conservation. Biodiversity and Conservation 12:1445-1453

Frey, B., J. Kremer, A. Rudt, S. Sciacca, D. Matthies, & P. Luscher. 2009. Compaction of forest soils with heavy logging machinery affects soil bacterial community structure. European Journal of Soil Biology 45:312-320

“Machine passes, irrespective of the compaction level, considerably modified soil structural characteristics at two soil depths (5-10 cm; 15-20 cm). Total porosity decreased up to 17% in the severe compaction, including large decreases in macroporosity (>50 mu m). Reduction in macroporosity was associated with higher water retention and restricted gas exchange in compacted soils. The strongest effect was observed in the severely compacted wheel tracks where air and water conductivities were reduced permanently to 10% or even lower of the original conductivities of undisturbed soils. Very slow drainage in combination with a dramatically reduced gas permeability led to unfavorable soil conditions in severely disturbed traffic lanes reflecting the changes in the total bacterial community structures at both soil depths. Additionally, microbial biomass C tended to be lower in compacted soil.”

Frumhoff, P.C .1995. Conserving wildlife in tropical forests managed for timber – to provide a more viable complement to protected areas. BioScience 45:456-463

Fuhr, M., C. Julliot, B. Dutreve, & O. Brunaux. 2001. Biodiversity in the planning of the forests of Guyana. Revue Forestiere Francaise Numero Special (Nancy)

Gajaseni, J. & C. F. Jordan. 1990. Decline of Teak Yield in Northern Thailand: effects of Logging on Forest Structure. Biotropica 22: 114-118.

Between 1971 and 1985 Teak harvests dropped to 1/10. This drop has been attributed to shift to increased intensity in agriculture. This paper suggests that the reduction is due to over harvest of large trees in the past, leaving only trees that are too small to harvest and killing seedlings at that time.

Ganzhorn, J. U. 1995. Low-level forest disturbance effects on primary production, leaf chemistry and lemur populations. Ecology 76: 2084-2096.

Ganzhorn, J. U. , A. W. Ganzorn, J. P. Abraham, L. Andriamanarivo & A. Ramananjatovo. 1990. The impact of selective logging on forest structure and tenrec populations in western Madagascar. Oecologia 84: 126-133.

Gaston, K.J., T.M. Blackburn, & K.K. Goldewijk. 2003. Habitat conversion and global avian biodiversity loss. Proceedings of the Royal Society of London Series B 270: 1293-1300

Gatinot, B. L. 1976. Les milieux frequentes par le colobe bai d'Afrique de l'ouest (*Colobus badius temmincki Kuhl 1820*) en Senegambia. Mammalia, 40: 1-12

Gautier-Hion, A. & G. Michaloud. 1989. Are figs always keystone resources for tropical frugivorous vertebrates? A test in Gabon. Ecology 70: 1826-1833.

Gautier-Hion, A. , J. M. Duplantier, F. Quris, F. Feer, C. Sourd, J. P. Decoux, G. Dubost, L. Emmons, C. Erard, P. Hecketsweiler, A. Moungazi, C. Roussilhon & J. M. Thiollay. 1985. Fruit characteristics as a basis for fruit choice and seed dispersal in a tropical forest vertebrate community. Oecologia 65: 324-337

Gaylard, A. & G.I.H. Kerley. 2001. Habitat assessment for a rare, arboreal forest mammal, the tree hyrax *Dendrohyrax arboreus* African Journal of Ecology 39: 205-212

Gent, J.A., Ballard, R. And Hassan, A.E. 1983. The impact of harvesting and site preparation on the physical properties of lower coastal plain forest soils. *Soil Science Society of America - Journal* 47:595-598.

Gerhardt, K. & C. Todd, 2009. Natural regeneration and population dynamics of the tree *Afzelia quanzensis* in woodlands in Southern Africa. African Journal of Ecology 47:

Gerrish, G. 1989. Comparing crown growth and phenology of juvenile, early mature, and late mature *Metrosideros polymorpha* trees. Pacific Science 43: 211-222

Gerwing, J.J. 2002. Degradation of forests through logging and fire in the eastern Brazilian Amazon Forest. Ecology and Management 157:131-141

Compares the impacts of varying intensities of logging and fire (from none to logged and heavily burned) on forest structure and composition in 14, 10 m x 500 m plots. Notes significant loss in biomass, significant crown and stem damage, and that recovery of the forest structure is likely to be hampered by the abundance of many small lianas post fire and logging. Regenerating vegetation is more likely to promote fires in the future.

Ghana Forest Service. 1998a. Manual of Procedures forest resource management planning in the HFZ. Unpublished. Forest Service. Accra

Section A. Strategic planning; Section B. Operational Planning; Section C. Sustainable timber production on reserve; Section D. Stock survey and Yield Allocation; Section E. Preparation of timber harvesting schedules; Section F. Controlled timber production off-reserve

Ghana Forest Service. 1998b. A logging manual for Ghana. 26 pp + Appendices.

Rules and guidelines for practice and monitoring of logging in Ghana, with samples of all required forms in Appendices.

Ghartey, K. K. F. 1992. The evolution of forest management in the Tropical High Forest of Ghana. Paper presented at conference sur la conservation et utilisation rationelle de la foret dense d'Afrique centrale et de l'ouest. World Bank/ADP/IUCN Abidjan, Ivory Coast.

Ghazoul, J. 2002. Impact of logging on the richness and diversity of forest butterflies in a tropical dry forest in Thailand. Biodiversity and Conservation 11: 521-541

Ghazoul, J. , K. A. Liston, & T. J. B. Boyle. 1998. Disturbance induced density-dependent seed set in *Shorea siamensis* (Dipterocarpaceae), a tropical forest tree. Journal of Ecology 86: 462-473.

High pollination rates and high abortion rates, but more abortion in the disturbed site perhaps due to selfing. Three sites in Thailand differing in disturbance intensity (protected area with buffer zone), and consequent differences in tree density. Trees pollinated by *Trigona* bees, significantly reduces inter-tree journeys with distance. Variation in seed set negatively correlated with distance to nearest conspecific (96 to 62 flowering trees/ha reduced success a bit, but sharp declines to 9 trees/ha). Reproductive success declines with population density.

Ghazoul, J. & M. McLeish. 2001. Reproductive ecology of tropical forest trees in logged and fragmented habitats in Thailand and Costa Rica. *Plant Ecology* 153: 335–345.

Gillespie, T. R., S.R. Balcomb, C.A. Chapman, J.P. Skorupa, & T.T. Struhsaker. 1999. Long-term effects of logging on African primate communities: A 28-year comparison from Kibale National Park, Uganda. American Journal of Primatology 49: 1-57

Gillespie, T., C.A. Chapman, & E.C. Greiner. 2003. Impact of logging-induced ecological change on disease dynamics in African forest primates. American Journal of Primatology 60: 148

Gillespie, T.R., D. Morgan, C. Sanz, & K. Cameron. 2009. Logging creates unanticipated threat to ape health and conservation in Equatorial Africa, 32nd Annual Meeting of the American-Society-of-Primatologists. American Journal of Primatology 71:92

Gillman, G. P. , D. F. Sinclair, R. Knowlton & M. G. Keys. 1985. The effect on some soil chemical properties of the selective logging of a north Queensland forest. Forest Ecology and management 12: 195-214.

Properties of red granitic soils in Queensland rainforests were measured after selective logging and 1, 2, 4 yrs later. The sites were stratified into four disturbance classes; 'snig tracks', crown litter accumulation and light penetration. Snig track disturbance altered soils most, with loss of organic C, but this was found to accumulate in mounds at the track side. After 4 years N, Ca, Mg and K levels over the whole site had not altered significantly from initial values, though organic C declined by 15%, P was not measured. Basal area had grown by 2. 07 m^2/ha during the study period.

Gilmour, D. A. 1971. The effects of logging on streamflow and sedimentation in a north Queensland rainforest catchmment. Commonwealth Forestry Review 50: 38-48.

Givnish, T. J. 1984. Leaf and canopy adaptations in tropical forests. Pp. 51-83 in Medina, E., H. A. Mooney & C. Vazques-Yanes (eds.). Physiological ecology of plants of the Wet Tropics. Junk. The Hague.

Goldingay, R. & R. Kavanagh, 1991. The yellow-bellied glider: a review of its ecology and management considerations. Pp. 365-376. in Lunney, D. (ed.) Conservation of Australia's forest fauna, Mosman: Royal Zoological Society of New South Wales.

Golley, F.B. 1983. The abundance of energy and chemical elements. In: *Ecosystems of the World 14A. Tropical Rain Forest Ecosystems: Structure and Function*. Golley, F.B. (ed.). Elsevier Scientific Publishing Company Incorporated. New York, NY10163.

Goncalves, F.G. & J.R. dos Santos. 2008. Floristic composition and structure of a sustainable forest management unit at Tapajos National Forest, Para, Brazil. Acta Amazonica 38: 229-244

Gormley, L. 1997. The impacts of increased utilisation of lesser used species - A literature review. Oxford Forestry Institute/International Tropical Timber Organisation (ITTO), 41 pp.

Gourlet-Fleury, S., G. Comu, S. Jesel, H. Dessard, J.G. Jourget, L. Blanc, & N. Picard. 2005. Using models to predict recovery and assess tree species vulnerability in logged tropical forests: A case study from French Guiana. Forest Ecology and Management 209: 69-86

This paper finds that the simple matrix models StoMat and SELVA predict diameter class distributions as reliably as more complicated ones, and are sufficient to assess the recovery of a species' exploitable stock even in the long term, or at least assess the (un)sustainability of particular harvesting regimes.

Gorchov, D. L. , F. Cornejo, C. Ascorra, M. Jaramillo, T. H. Fleming (ed.) & A. Estrada. 1993. The role of seed dispersal in the natural regeneration of rain forest after strip cutting in the Peruvian Amazon. Vegetatio 107: 339-349.

30 x 150m strips cleared. Some resprouts, but more seed regeneration. Less seed rain in strips than adjacent forest, but number of bat and wind dispersed species more even. Bat species

composition in strips more similar than bird species. Many forest birds do not venture into strip. Strip edges intermediate. Abundance of *Cecropia* type pioneers renders the silvicultural technique not very succesful.

Gould, S. J. 1996. Allometry and size in ontogeny and phylogeny. Biological review 41: 587-640

Gray, M.A., S.L. Baldauf, P.J. Mayhew, & J.K. Hill, 2007. The response of avian feeding guilds to tropical forest disturbance. Conservation Biology 21:131-141

Gray, B. 1972. Economic tropical forest entomology. *Annual Review Entomology* 17: 313-354.

Greene, D. F. & E. A. Johnson. 1994. Estimating the mean annual seed production of trees. Ecology 75: 642-647.

For temperate canopy trees seed production (number) highly inversely correlated with mean seed mass (Q=344 x mean_mass-·^{561}). However, large seeded plants produce more total annual crop than small seeded ones, although small seeded ones invest more in ancillary reproductive tissue.

Grieser Johns, A. 1996. Bird population persistence in Sabahan logging concessions. Biological Conservation.75: 3-10.

Grieser Johns, A. 1997. Timber production and biodiversity conservation in tropical rain forests. Cambridge: Cambridge University Press.

Grieser Johns, A. & B. Grieser Johns. 1995. Tropical primates forest primates and logging: long-term co-existence? Oryx 29: 205-211.

Grogan, J. & J. Galvao. 2006. Factors limiting post-logging seedling regeneration by big-leaf mahogany (*Swietenia macrophylla*) in southeastern Amazonia, Brazil, and implications for sustainable management. Biotropica 38: 219-228

Grogan, J., S.B. Jennings, R.M. Landis, M. Schulze, A.M.V. Baima, J.D.A. Lopes, J.M. Norghauer, L.R. Oliveira, F. Pantoja, D. Pinto, J.N.M. Silva, & E. Vidal. 2008. What loggers leave behind: Impacts on big-leaf mahogany (*Swietenia macrophylla*) commercial populations and potential for post-logging recovery in the Brazilian Amazon. Forest Ecology and Management 255: 269-281

Grogan, J; Schulze, M; Galvao, J. 2010. Survival, growth and reproduction by big-leaf mahogany (Swietenia macrophylla) in open clearing vs. forested conditions in Brazil. New Forests 40: 335-347

Grove, S.J. 2002. Saproxylic insect ecology and the sustainable management of forests. Annual Review of Ecology and Systematics 33 :1-23

Guariguata, M.R., J.J.R. Adame, & B. Finegan. 2000. Seed removal and fate in two selectively logged lowland forests with contrasting protection levels. Conservation Biology 14: 1046-1054

Guariguata, M. R., & J.M. Dupuy. 1997. Forest regeneration in abandoned logging roads in lowland Costa Rica. Biotropica 29: 15-28.

Guariguata, M. R. & M. A. Pinard. 1998. Ecological knowledge of regeneration from seed in tropical trees: implications for natural forest management. Forest Ecology and Management 112: 87-99.

Guariguata, M. R. & R. Ostertag. 2001. Neotropical secondary forest succession: changes in structural and functional characteristics. Forest Ecology and Management 148: 185-206.

Guevara, S., S. E. Purata & E. van der Maarel. 1986. The role of remnant trees in tropical secondary succession. Vegetatio 66: 77-84.

Abandoned fields in Los Tuxtlas, Mexico, large remnant forest trees form clumped regeneration nucleii, due to perching birds.

Guo, S.T., W.H. Ji, B.G. Li, & M. Li. 2008.. Response of a group of Sichuan snub-nosed monkeys to commercial logging in the Qinling Mountains, China. Conservation Biology 22: 1055-1064

Gullison, R. E. & J. J. Hardner, J. J. 1993. The effects of road design and harvesting intensity on forest damage caused by selective logging; empirical results and a simulation model from Bosque Chimanes, Bolivia. Forest Ecology and management 59: 1-14.

Gutierrez-Granados, A.U. & G. Dirzo. 2010. Indirect effects of timber extraction on plant recruitment and diversity via reductions in abundance of frugivorous spider monkeys. Journal of Tropical Ecology 26: 45-52

Gutierrez-Granados, G. 2011. Effect of logging on rodent scatter-hoarding dynamics in tropical forests: implications for plant recruitment. Integrative Zoology 6: 74-80

Gutierrez-Granados, G; Perez-Salicrup, DR; Dirzo, R. 2011. Differential diameter-size effects of forest management on tree species richness and community structure: implications for conservation. Biodiversity and Conservation 20: 1571-1585

Compares forest reserves and 10 year-old logged areas in the Yucatan Peninsula. Paired design in three independent sites estimate the effects of logging on tree species richness, diversity, composition and structure. 4 size-classes were used 1-5, 5-10, 10-25, and >25 cm DBH. Species richness in the smaller and larger diameter-size classes was significantly lower in logged areas. Floristic composition was also different between logged and unlogged areas, with a trend towards more secondary forest associated species and less primary forest associated species in logged areas, and a higher density of species represented by a single individual in unlogged reserves.

Gyimah, A. 1986. Flowering and fruiting periods of some indigenous forest trees. Technical Bulletin. Forest Products Research Institute, Ghana. 1-8.

G¢mez-Pompa, A. , T. C. Whitmore & M. Hadley (eds.). 1991. Rain forest regeneration and mangement. Man and the Biosphere Series Vol. 6. UNESCO, Paris & Parthenon. 457 pp.

Haila, Y. & Hanski, I.K. 1984 Methodology for studying the effects of habitat fragmentation on land birds. Annales Zoologici Fennici 21: 393–397

Hall, J. B. 1987. Conservation of forest in Ghana. Universitas. University of Ghana, Accra. 33-42.

Largely a historical review, with data on logging history and deforestation.

Hall, J. B, R. Kumar & A. A. Enti. 1972. The obnoxious weed *Eupatorium odorata* (Compositae) in Ghana. Ghana Journal of Agricultrual Science 5: 75-78.

Records the recent introduction and rapid spread of this species into disturbed forest in Ghana.

Hall, J. B. D. U. U. Okali & J. M. Lock. 1975. Night illumination and flowering in an indigenous West African forest tree *Hildegardia barteri* (Mast.) Kosterm. Bull. Inst. Fond. Afr. Noire Ser. A37: 282-297.

Hall, J. B. & M. D. Swaine. 1976. Classification and ecology of closed canopy forest in Ghana. Journal of Ecology 64: 913-951

Hall, J. B. & M. D. Swaine. 1980. Seed stocks in Ghanaian forest soils. Biotropica 12: 256-263.

Experiments show certain pioneer species commonly regenerate from dormant supplies in the soil.

Hall, J. B. and M. D. Swaine. 1981. Distribution and Ecology of plants in tropical rain forest. Junk,The Hague.

Definitive book summarising floristic composition of Ghana's forests.

Hall, J.S. 2008. Seed and seedling survival of African mahogany (*Entandrophragma spp.*) in the Central African Republic: Implications for forest management. Forest Ecology and

Management 255:292-299

Hall, J.S., D.J. Harris, V. Medjibe, & P.M.S. Ashton. 2003. The effects of selective logging on forest structure and tree species composition in a Central African forest: implications for management of conservation areas. Forest Ecology and Management 183: 249-264

Compares unlogged, 6-month and 18-year post-harvest forest stands. Stem densities of both saplings and trees in unlogged forest were significantly higher than those in forest sampled 18 years after logging, but little difference in tree species composition and diversity. There is inadequate recruitment of *Entandrophragma cylindricum* and *E. utile*, the principal timber species, to justify continued timber extraction. Data indicate a significant shift in canopy dominance from shade intolerant to shade-bearing species, due to insufficient canopy disturbance. Nevertheless, an abundance of other top quality timber species remains after selective removal of African mahogany and these forests will remain attractive to loggers long after the elimination of *Entandrophragma* spp. 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.

Halle, F. , R. A. A. Oldeman & P. B. Tomlinson. 1978. Tropical trees and forests. An architectural analysis. Springer-Verlag, New York. 441 pp.

Details of their (botanical) architectural models

Hamill, D. N. & S. J. Wright. 1986. Testing the dispersion of juveniles relative to adults: a new analytic method. Ecology 67: 952-957.

Relative dispersion calculated e.g. for seedlings in sub-sample within adult tree sample, by comparing accumulative frequency with null hypothesis based on % of area at various distances from adult. Used Kolmogorov-Smirnov to test for significant deviations. For modelled scenarios, the method accurately highlights random distributions; clumped seedlings near parents; clumped seedlings followed by greater morality near parents suggested clumping or over-dispersion depending on scale; patchy resource patterns independent of parent location caused rejection of the null hypothesis only 21% of the time

Hamilton, G. J. 1969. The dependence of the volume increment of individual trees on dominance, crown dimensions and competition. 42: 133-144.

Hammond, D. S. , S. Gourlet Fleurym, P. van der Hout , H. ter Steege & V. K. Brown. 1996. A compilation of known Guianan timber trees and the significance of their dispersal mode, seed size and taxonomic affinity to tropical rain forest management. Forest Ecology and management 83: 99-116.

List of 170 spp. with details of seed size and dispersal mode. 50% are mammal dispersed, 21% bird dispersed, 20% wind-dispersed, <8% no agent. Disproportionate harvesting occurs of mammal-dispersed spp. relative to their total volume. Recommends exploiting species within same mode in relative proportion to their availability.

Hamzah, Z. 1978. Some observations on the effects of mechanical logging on regeneration, soil and hydrological conditions in East Kalimantan. BIOTROP Special Publ. 3: 73-78

Hanson, T., S. Brunsfeld, & B. Finegan. 2006. Variation in seedling density and seed predation indicators for the emergent tree Dipteryx panamensis in continuous and fragmented rainforest. Biotropica 38: 770-774

Harrington, G. N., A.N.D. Freeman & F.H.J. Crome. 2001. The effects of fragmentation of an Australian tropical rain forest on populations and assemblages of small mammals. Journal of Tropical Ecology 17: 445-456

Harrington, T. B. , J. C. Tappeiner, & R. Warbington 1992. Predicting crown sizes and diameter distributions of tanoak, Pacific madrone, and giant chinkapin sprout clumps. Western Journal of Applied Forestry 7:103-108

Harris, R. 2006. Can't log the forest for the trees? Newly revealed effects of selective logging emphasize the need to enforce best management practices. American Scientist 94: 120-121

Hart, T. B. 1995. Seed, seedling and sub-canopy survival in monodominant and mixed forests of the Ituri Forest, Africa. Journal of Tropical Ecology 11:443-459.

Gilbertiodendron dewevrei in a matrix with *Julbernardia seretii*. For *J. s.* % mortality was lower where seed density was higher, but not for *G. d.* Mast years satiate mammalian predators but not beetles, which were major source of predation. *G. s.* had lower mortality than *J. s.* . Ability to persist in Understory may explain greater canopy dominance, in spite of seedling trends.

Hartshorn, G. S. 1978. Tree falls and tropical forest dynamics. In: P. B. and Zimmermann, M. H. (eds.). Tropical Trees as Living Systems. Tomlinson, Cambridge University Press, U. K.

Hartshorn, G. S. 1990. Natural forest management by the Yanesha forestry cooperative in Peruvian Amazonia. Pp.128-138 in Anderson, A.B. (ed.) Alternatives to deforestation: steps towards sustainable use of the Amazon rainforest, New York: Columbia University Press.

Hawthorne, W. D. 1989. The regeneration of Ghana's forests. Unpublished. report to ODA/Ghana planning branch.

Although this report has been cited in literature, it has in effect been superseded (Hawthorne, 1995). There is nevertheless certain relevant information, particularly in the graphs, that found no place in the update.

Hawthorne, W. D. 1990. Field guide to the forest trees of Ghana. Natural Resources Institute, Chatham. 278 pp.

A guide to all the c. 670 trees in Ghana which can exceed 5 cm dbh, with some names revised since Flora of West Tropical Africa.

Hawthorne, W. D. 1992. Forestry, Dragons and Genetic Heat. Paper presented at seminar on conservation in Africa. Wildlife Conservation International, Washington.

First presentation and approximation of Red (Scarlet, Red, Pink star) categories of economic threat, with inventory and export figures for timber to support it. Also discusses Genetic Heat Index etc. subsequently explained in more details elsewhere.

Hawthorne, W. D. 1993. Forest regeneration after logging: findings of a study in the Bia South Game Production Reserve, Ghana. ODA Forestry Series 3. Natural Resources Institute, Chatham.

Analysis of regeneration after logging, with ordinations and other summary of the species composition of skid trails, logging roads, felled tree gaps and undisturbed 'Twilight zone' forest, lead to the definition of Pioneer, Non Pioneer Light Demander (NPLD) and Shade-beater guilds. Poor regeneration of all species on old road surfaces and loading bays; Pioneers dominate regeneration of more disturbed areas; NPLDs most common in skid trails. Species composition of logged areas different from 'natural forest'. Natural treefall gaps found to have more climbers than felled tree gaps.

Hawthorne, W. D. 1994. Fire damage and forest regeneration in Ghana. ODA Forestry Series 4. Natural Resources Institute, Chatham. 53pp.

Details of thee patterns of regeneration in forest at Asukese F. R. after area have been subject to fire damage.

Hawthorne, W. D. 1995a. Ecological profiles of Ghanaian forest trees. Tropical Forestry Papers 29. Oxford Forestry Institute, UK.

Summary of autecology of all species of tree in Ghana which exceed 5 cm dbh, with explanatory notes about guilds, stars and crown exposure trends.

Hawthorne, W. D. 1995b. FROGGIE-Forest Reserves of Ghana: Graphical Information Exhibitor (manual for the program). IUCN, Gland, Switzerland and Cambridge, UK.

Description of the data held FROGGIE map-database, and a manual for its operation. The program allows inspection of inventory data for all tree species in Ghana, with distributional data for all (>2000) forest species. Data can be overlaid on maps of the forest types and Forest Reserves, or textual summaries can be viewed.

Hawthorne, W. D. 1996. Holes and the sums of parts in Ghanaian forest: regeneration, scale and sustainable use. Proceedings of the Royal Society of Edinburgh 104b (This volume edited by Swaine *et al.*): 75-176.

Highlights how factors across many scales, from bigeographic to local ecological, interact to influence local forest composition. Even over short distances, the composition of the forest on a scale of hundreds of hectares will influence the outcome of a local disturbance such as logging. As the broader scale picture is far from deterministic, purely eco-physiological influences will not explain forest recovery. Also, 'refugia' are not discrete biogeographical phenomena, but exist on all scales and need to be documented and understood before any sort of sustainable forest production can be achieved. The paper also provides a complete check-list with the guilds and conservation status of all forest species in Ghana.

Hawthorne, W. D. & M. Abu-Juam. 1995. Forest protection in Ghana. IUCN, Gland, Switzerland and Cambridge, UK

Review of forest reserve condition and history in Ghana, with recommendations for improvement. Results of a botanical survey, including a vegetation scoring system of 'Genetic heat Index' and 'Economic Index', which provides a conservation priority 'league table' for patches of forest in Ghana. Recommendations are made for a new framework of protection policy which respects such patterns on various scales.

Hawthorne, W. D., D. L. Filer & D. J. Turnbull, 1999. Tree data management, mapping, and the development of the TREMA software. International Forestry Review. 1:87-96

Summary of TREMA software, with examples from the current and other studies.

Hawthorne W.D. & M.P.E. Parren, 2000. How important are the forest elephants to the survival of woody plant species in upper Guinean forests? Journal of Tropical Ecology 16: 133-150

Heinrich, R. (ed.). 1978. Mountain forest roads and harvesting. Technical report of the second FAO/Austria training course, Austria 1978. FAO. FAO, Rome. 1-154.

A multi-author volume on all aspects of the title. See FAO 1983 for updated version.

Heinrich, R. 1995. Environmentally sound harvesting to sustain tropical forests. IUFRO XX World congress report (Tampere, Finland). IUFRO secretariat, Austria. 436-446.

Several FAO and grey-literature reports are in effect summarised. General discussion leading up to presentation of the FAO programme on environmentally sound forest harvesting and engineering. Low impact harvesting has 4 components. Harvest planning. Topographical and census data (cf Marn & Jonkers, 1982). Felling operations: Mark trees well before felling, for felling or retention as seed trees. Directional felling feasible for 60-70% trees cut. Wood extraction systems: Keep skidding etc. to a minimum - easier with harvest planning. Cables, balloons and cycolcraft mentioned.

Hendrison, J. 1990. Damage controlled logging in managed tropical rain forest in Suriname. Pudoc, The Netherlands.

Part of CELOS, method devised to reduce logging damage. Felling damage as gaps and no. damaged trees. Directional felling to facilitate skidding reduced damage a lot. Plan skid trails on maps.

Hens, L. 2006. Indigenous knowledge and biodiversity conservation and management in Ghana. Journal of Human Ecology 20: 21-30

Henwood, A. 1986. Moth trapping in the rain forest of Borneo. Report to Yayasan Sabah, Kota Kinabalu.

Herault, B; Ouallet, J; Blanc, L; Wagner, F; Baraloto, C. 2010. Growth responses of neotropical trees to logging gaps. Journal of Applied Ecology 47: 821-831

Hernandez-Diaz, J. C. & M. Delgado-Pacheco. 1995. Damage evaluation to remaining standing trees

in a timber yarding operation (case study). Abstract: Proc. XX IUFRO world congress. 221.

Mexico: 1.845 m^3/ha of residual commercial size trees were damaged by timber yarding with a 'motogrua' yarding crane in a forest with 41 m^3/ha (or 1.9 trees/ha.).

Hertel, D., C. Leuschner, M. Harteveld, & M. Wiens, 2007. Fine root mass, distribution and regeneration in disturbed primary forests and secondary forests of the moist tropics. Pp 89-108 in Tscharntke, T., C. Leuschner, M. Zeller, E. Guhardja, & A. Bidin, (eds.) Stability of Tropical Rainforest Margins: Linking Ecological, Economi and Social Constraints of Land Use and Conservation International Symposium on Stability of Tropical Rainforest Margins SEP, 2005. Georg-August-Univ Goettingen, Goettingen, Germany

Hetherington, J. C. 1967. Crown diameter:stem diameter relationships in managed stands of sitka spruce. Commonwealth Forestry Review 46: 278-281.

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Heydon, M.J. & P. Bulloh. 1996. The impact of selective logging on sympatric civet species in Borneo. Oryx 30: 31-36.

Heydon, M.J. & P.Bulloh. 1997. Mousedeer densities in a tropical rainforest: the impact of selective logging. Journal of Applied Ecology 34: 484-496

Hicks, T.C., R.S. Fouts, & D.H. Fouts. 2009. A Survey of Chimpanzees (*Pan troglodytes*) and Gorillas (*Gorilla gorilla)* in the Selectively Logged Ngotto Forest, Central African Republic. Journal of Applied Animal Welfare and Science 12:165-188

Hietz-Seifert, U., P. Hietz, & S. Guevara. 1996 Epiphyte vegetation and diversity on remnant trees after forest clearance in southern Veracruz, Mexico. Biological Conservation 72: 103-111

Hill, J.K. 1999. Butterfly spatial distribution and habitat requirements in a tropical forest: impacts of selective logging. Journal of Applied Ecology 36: 564-572

Hill, J.K, K.C. Hamer, M.M. Dawood, J.Tangah, & V.K. Chey. 2000. Rainfall but not selective logging affect changes in abundance of tropical forest butterfly in Sabah, Borneo. Journal of Tropical Biology 19: 35-42

Hill, J.K., K.C. Hamer, L.A. Lace, & W.M.T. Banham. 1995. Effects of selective logging on tropical forest butterflies on Buru, Indonesia.Journal of Applied Ecology 32: 754-760

Hilton, R. G. B. 1987. Nutrient cycling in tropical rainforests: Implications for management and sustained yield. Forest Ecology and Management 22: 297-300

Hitimana, J., J.L. Kiyiapi, & J.T. Njunge. 2004. Forest structure characteristics in disturbed and undisturbed sites of Mt. Elgon moist lower montane forest, western Kenya. Forest Ecology and Management 194: 269-291

Regeneration and recruitment patterns of the forest and of individual tree species varied among heavily and lightly logged-over sites; and in spite of a good overall forest regeneration, this did not necessarily mirror the regeneration status of constituent tree species. The forest is classified as an under-stocked tropical mixed rain forest.

Hladik, A. & D. Mitja. 1996. Seedlings, saplings and tree temperaments: potential for agroforestry in the African rain forest. Pp173-192, Swaine M.D (ed.) The ecology of tropical forest seedlings. Man and the Biosphere Series V:17 UNESCO and the Parthenon Publishing Group Paris.

Discusses the various types of seedling and how they relate to dispersal and sapling growth. Growth and mortality were followed in Gabon, Makoukou forest in two PSPs (400x10m; 1800x5m), for trees >5 or >30 cm dbh. Overall mortality was 10%, compensated by

recruitment. Pioneers (*Macaranga, Ficus, Croton, and Alstonia*) have a distinct 'Type 1' seedling. Type 1 seedlings were also amongst non-pioneers though. In fallows, many more Type 1 seedlings (24 pioneers - good correspondence with Ghana classification) were found.

Hogberg, P., & J. Wester. 1998. Root biomass and symbiosis in *Acacia mangium* replacing tropical forest after logging. Forest ecology and Management 102: 333-338

Holbech, L.H. 2009. The conservation importance of luxuriant tree plantations for lower storey forest birds in south-west Ghana. Bird Conservation International 19: 287-308

Holbech, L.H. 2005. The implications of selective logging and forest fragmentation for the conservation of avian diversity in evergreen forests of south-west Ghana. Bird Conservation International 15: 27-52

Holdsworth, A.E., & C. Uhl. 1997. Fire in Amazonian selectively logged rainforest and the potential for fire reduction Ecological applications 7: 713-725

Holloway, J. D. 1984. Moths as indicator organisms for categorizing rain-forest and monitoring changes and regeneration processes. Pp 235-242 in Chadwick, A. C & S. L. Sutton, (eds.) Tropical rain-forest: the Leeds symposium, Leeds: Leeds Philosophical and Literary Society.

Holloway, J.D., A.H. Kirk-Spriggs & V.K Chey. 1992. The response of some rain forest insect groups to logging and conversion to plantations. Phil. Trans. R. Soc. London B 335: 425-436

Hopkins, M. S. & A. Graham. 1983. The species composition of soil seed banks beneath lowland tropical rain forests in North Queensland, Australia. Biotropica 15: 90-99.

Hopkins, M. S., J. Kikkawa, A.W. Graham, J.G. Tracey, & L.J. Webb. 1977. An ecological basis for the management of rainforest. Pp. 57-66 in Munroe, R. & N. C. Stevens (eds.) The border ranges: a land use conflict in regional perspective, Brisbane: Royal Society of Queensland.

Horn, H. S. , 1971. The adaptive geometry of trees. Princeton University Press. Princeton.

Multi-layer and mono-layer crowned trees discussed for temperate forests, hypothesising that mutli-layer trees give access to more sunlight therefore are more productive.

Horne, R. & J. Gwalter. 1984. Recovery of rainforest overstorey following logging. I. Subtropical rainforest. Australian Forest Research 13: 29-44.

An area 3.9 ha of 14 yr old regrowth (following 70-80% basal area removal) measured 5 times; 100-220 years estimate for recovery, but only 30-60 years needed if 30% basal area removed. A growth model is used, assuming the overstorey composed of trees>30m high (when dbh 46cm); When mature, overstory BA increment is 0; after logging residual overstory species respond to release; 'recovery' has occurred when BA reaches equilibrium value; NetBA growth of recovering overstory declines with time due to increasing competition and mortality; all overstory and potential overstory trees have an equal chance of mortality during recovery period. Trees with >10cm dbhn growth increments increased after logging.

Horne, R., G. Watts, & G. Robinson. 1991. Current forms and extent of retention areas with a selectively logged blackbutt forest in NSW: a case study. Australian Forestry 54: 148-153.

Hostettler, S. 1996. Dispersal and regeneration probability in wind-, animal- and explosively-dispersed timber trees. B.Sc Hons. Dis. Environmental Science, University of Aberdeen.

Comparison of different dispersal modes; 7 species, seedling distributions and regeneration probabilities, with the ultimate aim of developing models applicable to forest regeneration after logging. All seedling distributions are leptokurtic, negative exponential from the mode outwards. Median distance of seedling from older cohorts is significantly higher than median dispersal distance, suggesting higher mortality near parent. In the equation. ln(y)=a+mx, where y=density & x=distance and d1=radial distance where 1 seedling expected.

WIND: Nesogordonia lny=9. 17-0. 25x r2=. 9 36; Pterygota lny=7. 85-0. 2x r2=. 95 40; Khaya lny=6. 39-0. 24x r2=. 85 26

ANIMAL: Aningeria lny=9. 93-0. 32x r2=. 98 31; Cola gig. lny=8-0. 24x r2=. 9 33; Antiaris lny=8. 28-0. 23x r2=. 97 36
EXPLOSIVE: Bussea lny=5. 98-0. 23x r2=. 91 26

No sig. diff. between slopes, but max. distance varies. Herbivory damage declines for *Pterygota*, increases for *Nesogordonia* and showed little pattern for other species. Animal dispersed seedlings generally more abundant, esp. under mother. The concept of aconstant for a species, describing how much forest could be restocked by a single mature tree is discussed. For all species, dispersal greater than 100m from the tree is vanishingly rare.

Howe, H. & J. Smallwood. 1982. Ecology of seed dispersal. Annual Review of Ecology and Systematics 13: 201-228.

Discuss general aspects of seed dispersal, plus gives typical profiles of dispersal types for different forests.

Howlett, B.E. & D.W. Davidson .1996. Dipterocarp seed and seedling performance in secondary logged forest dominated by Macaranga spp. Pg 256-266 in Appanah, S., & K.C. Khoo (eds.) Proceedings fifth round table conference on Dipterocarps, Chang Mai, Thailand 7-10 November 1994

Huang, M., G.P. Asner, M. Keller, & J.A. Berry, 2008. An ecosystem model for tropical forest disturbance and selective logging. Journal of Geophysical research-Biogeosciences 113:

Huang, MY; Asner, GP. 2010. Long-term carbon loss and recovery following selective logging in Amazon forests. Global Biogeochemical Cycles 24, art.no.-GB3028

Hubbell, S.P. 1980. Seed predation and the coexistence of tree species in tropical forests. Oikos 35: 214-229.

Hubbell, S.P. 1999. The maintenance of diversity in a neotropical tree community: Conceptual issues, current evidence and the challenges ahead. Pp 17-44. in Forest Biodiveristy, Research and Monitoring and Modeling.Vol 20. Man and the Biosphere Series, UNESCO and Parthenon Paris.

Based largely on BCI data. Density dependence in 25ha. quadrat scale across 40ha.. Small trees are often old (Estimated from polynomial regression on growth rates >1cm, danger of overestimate, because growth rates included those dying, hence only 10% fastest growth rates) For 1cm DBH trees, the Median is 16.6 yrs. *Ouratea lucens* >80 yrs. *Trichilia* and *Alseis* canopy trees c 20-25 yrs. old at 1cm. *Cecropia* and *Zanthoxylum* <1 yr at 1cm. Non pioneer species spend long time in Understory, hence relative abundance determined here. 1/3 to 1. 2 of parents of a sapling cohort may have died, hence losing focal tree density dependence. Niches do not control the pesence/absence or current relative abundance of species: Immigration & extinction more are controlling. Density dependence on mortality and recruitment classical. However, BCI=density vague recruitment – population density sets an upper limit only. Stochastistic events affect year to year fecundity; seed and seedling mortality. e. g. *Trichillia*

Hubbell, S. P. & R. B. Foster 1986. Biology, chance and history and the structure of tropical forest communities. Pp 314-324 In Diamond, J. M. & T. J. Case. Community Ecology: Harper & Row, New York.

Hubbell, S.P., F.L. He, R. Condit, L. Borda-de-Agua, J. Kellner, & H. ter Steege, 2008. How many tree species and how many of them are there in the Amazon will go extinct? Proceedings of the National Academy of Sciences of the United Sates of America 105: 11498-11504

Hurlbert, S.H. 1984. Pseudoreplication and the design of ecological field experiments. Ecological Monographs 54: 187-211

Hubbell, S. P. , R. B. Foster, S. T. O'Brien, K. E Harms, R. Condit, B. Wechsler, S. J. Wright, & S. Loo de Lao. 1999. Light-gap disturbances, recruitment limitation, and tree diversity in a neotropical forest. Science 283: 554-557.

Discusses intermediate disturbance hypothesis, suggesting gap diversity promotes species diversity, based on 13 years study on >1200 gaps. Gaps increased seedling establishment and sapling densities, but the effect was non-specific. Species richness per stem the same in non-gap control sites. Species composition of gaps unpredictable. Strong recruitment limitation. 200 seed traps caught 260 species over 10yrs, but no seeds from >50 species with adults in the plot. Similar dispersal limitation evident for seedlings. Mortality in gaps a random thinning process, as no change seen in gaps over 12 years. Pioneers persisted in gaps over 12 years. Gaps promote whatever species in the area, neutrally.

Hughes, R. F., J. B. Kauffman & D. L. Cummings. 2002. Dynamics of aboveground and soil carbon and nitrogen stocks and cycling of available nitrogen along a land-use gradient in Rondônia, Brazil. Ecosystems 5: 244–259.

Hunter, M.L., 1993. Natural fire regimes as spatial models formanaging boreal forests. Biological Conservation 65: 115–120

Hussin, Bin. M.Z. & C.M. Francis. 2001. The effects of logging on birds in tropical forests in Indo Australia. Pg 167-192 in Fimbel, R.A., A. Grajal and J.G Robinson (eds.) The cutting edge: conserving wildlife in logged tropical forest. Columbia University Press New York USA

Hutchinson, J. & J. M. Dalziel. 1972. Flora of West Tropical Africa. 2nd edition Revised by Keay, R. W. J. & F. N. Hepper. Crown Agents, London.

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Study from Northumberland, UK. The thickest brash mat, composed of residues from 10 rows of trees, was unable to prevent compaction completely, but offers protection over passes on bare soil. The point at which compaction becomes detrimental remains uncertain.

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Huth, A., M. Drechsler, & P. Kohler. 2005. Using multicriteria decision analysis and a forest growth model to assess impacts of tree harvesting in Dipterocarp lowland rain forests. Forest Ecology and Management 207: 215-232

Using the rain forest growth model FORMIND, and a stochastic extension of the PROMETHEE method to select optimum endpoints, five scenarios proved to be optimum for a wide range of priorities concerning different forest functions. They all use reduced-impact logging and long logging cycles (>= 60 years), either with a minimum cutting limit of 50 or 60 cm stem diameter, or with medium logging intensities.

IIED/Forestry Department of Ghana. 1993. Study of incentives for the sustainable management of the tropical high forest of Ghana. Unpublished, draft report. IIED and Forestry Department, Accra, Ghana.

Ilisson, T. & H.Y.H. Chen. 2009. Response of Six Boreal Tree Species to Stand Replacing Fire and Clearcutting. Ecosystems 12: 820-829

Isabirye-Basuta, G. & J. M. Kasenene. 1987. Small rodent populations in selectively felled and mature tracts of Kiibale forest, Uganda. Biotropica 19: 260-266.

Two plots examined, one selectively felled, the other undamaged. 14 species of small rodents were examined. Two species were most abundant in both plots. Those species more commonly associated with savanna and edge habitats were more common in the logged area. Rodent densities were about equal in the plots but there was greater species diversity in the logged plot and was positively highly correlated with ground cover vegetation (higher in the felled plot). Rodent species diversity was inversely correlated with tree species diversity.

Iskandar, D.T. & D.Y. Setyanto.1999. Environmental impact assessment in four logged forest condition in South Kalimantan. Presented at Asia Pacific Congress on the Biology of the Environment. Singapore 21-24 November 1999

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Dryobalanops aromatica & *D. lanceolata* in areas where they have 17-20% of basal area. Distribution of <2yr seedlings restricted to <40m from adult. <1cm seedlings most dense around trees >30cm dbh. 1-5cm saplings and adults had negative spatial patterns (avoidance). but most 1-30cm poles were 15-20m from adults. Seedlings of both were randomly distributed with respect to light conditions (2 indices), but saplings were found under more open conditions.

Jack, W. H. 1960. A 'check' method applied to tropical high forest. Empire Forestry Review 39: 195-201.

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Jack, W. H. 1961. The spatial distribution of tree stems in a tropical high forest. Empire Forestry Review 40: 234-241.

Pra Anum, Ghana. 17,280 plots within 4320 acres, combined in various groups, shapes and sizes. Distribution not normal Gaussian nor Poisson but contagious negative binomial. Small sizes of *Triplochiton* and *Khaya ivorensis* related to larger sizes in the same areas. Long narrow samples across drainage gave lowest sample error.

Jack, S. B. & J. N. Long. 1991. Analysis of stand density effects on canopy closure: a conceptual approach. Trees 5: 44-49.

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Jans, L. , L. Poorter, R. S. A. R. Van Rompaey & F. Bongers. 1993. Gaps survey and forest zones in tropical moist forest in Ivory Coast. Biotropica 25: 258-269.

Janzen, D. H. 1967. Synchronisation of sexual reproduction of trees within the dry season in Central America. Evolution 21: 620-637

Janzen, D. H. 1970. Herbivores and the number of tree species in tropical forests. American Naturalist 104: 501-528.

Janzen, D. H. 1974. Tropical Blackwater rivers, animals and mast fruiting by the Dipterocarpaceae. Biotropica 6: 69-103.

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Janzen, D. H. , G. A. Miller, J. Hackforth-Jones, C. M. Pond, K. Hooper & D. P. Janos. 1976. Two Costa-Rican bat-generated seed shadows of *Andia inermis* (Leguminosae). Ecology 57: 1068-1075.

Bats visit *Andia* to eat the fruits, during this process many seeds fall, but mortality by weevil predation is high under the roosting trees. Seeds dropped in transit may have the best chance of maturing.

Jennings, S.B., N.D. Brown, D.H. Brown, D.H. Boshier, T.C. Whitmore & J.D.A. Lopes 2001. Ecology provides a pragmatic solution to the maintenance of genetic diversity in sustainable managed tropical rain forest. Forest Ecology and Management 154: 1-10

Most tropical rain forest tree species have many more individuals below the minimum size for commercial exploitation than above. The genetic diversity of these species will be little affected by logging, as the stems removed form only a small fraction of the total population. Similarly, for most species, disruption of normal mating patterns will either not occur or be transient, because reproduction commences at sizes well below felling limits, or because, after logging, juveniles will be recruited to the sexually mature size classes.

Strongly light-demanding species with a commercial value are most likely to suffer loss of genetic diversity from logging. Characteristically, these have populations in which only a small proportion of the total population lies in small size classes. In order to conserve genetic diversity, pre-felling silvicultural treatments will be required to increase the survival and growth of juveniles. Ecological and genetic research needs to focus on these light-demanding species.

Johns, A. D. 1981. The effects of selective logging on the social structure of resident primates. Malaysian Applied Biology 10: 221-226.

Johns, A. D. 1983a. Ecological effects of selective logging in a West Malaysian rain forest. PhD Thesis University of Cambridge

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Johns, A. D. 1985. Behavioural responses of two Malaysian primates (*Hylobates lar*) and (*Presbytis melalophos*) to selective logging: vocal behaviour, territoriality and non-emigration. International Journal of Primatology 6: 421-431.

Johns, A. D. 1986a. Effects of selective logging on the behavioural ecology of West Malaysian primates. Ecology 67: 684-694.

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Johns, A. D. 1989b. Timber, the environment and wildlife in Malaysian rain forests. Final Report to

O.D.A/NERC contract F3CR26/GI/05, Institute of South-east Asian Biology, University of Aberdeen, Aberdeen.

Johns, A. D. 1991a. Forest disturbance and Amazonian primates. Pp. 115-135.in Box, H.O. (ed.) Primate responses to environmental change, London: Chapman and Hall.

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Johns, A. D. & J.M. Ayres 1987. Southern bearded sakis beyond the brink. Oryx 21: 164-167.

Johns, A. D. & J.P. Skorupa. 1987. Responses of rainforest primates to habitat disturbance: a review. International Journal of Primatology 8: 157-191

Johns, A. G. 1988. Effects of 'selective' timber logging on rainforest structure and composition and some consequences for frugivores and folivores. Biotropica 20: 31-37.

51% of trees destroyed in W. Malaysia dipterocarp forest as a consequence of extracting 3.3% of trees. Damaged equally shared between all sizes and taxa. Food availability seriously reduced for frugivores and folivores. Selective logging removes only trees 145-192 cm dbh; 18 stems/ha. removed (24m^3/ha BA). Basal area reduced from 35 m^2 to to 18 m^2. Many colonisers attain 30 cm dbh in 5-6 yrs.

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Includes a theoretical minimum damage level by mathematical simulation i.e. 2 trees/ha=10% damage.

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A comprehensive review, but with a slight bias towards faunal matters.

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Effects of planning on tree felling, machine manoeuvring, skidding, loading bay construction and logging road construction. Planned logging used rubber wheels or bulldozer; vine cutting 2 years prior to logging and planned operation used directional felling. For each tree felled, unplanned logging, resulted in 16 more trees >10cm dbh damaged, and 100 m^2 extra area affected. Tree feeling caused most damage to other trees per ha. , with planning this was halved from 124 to 64 trees per ha. Probably profit margin increased by planning due to greater efficiency.

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Description of vegetation, methods and impacts of the CELOS silvicultural system. Emergent trees have a steeper crown radius/dbh line than 'commercial species' or non-commercial species, overtaking their lines at about 50 cm dbh. A 80cm dbh emergent has a radius of 10m; both commercial and non commercial are about 6-7m radius at this dbh. A logging experiment is described, with types of damage related to basal area removed.

Jonkers, W. B. J. & P. Schmidt 1984. Ecology and timber production in tropical rainforest in Suriname. Interciencia 9: 290-297.

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Logged over hill forest in Pahang. Estimated recovery of: 1. Bulk density, 2. Total porosity, 3. Saturated hydraulic conductivity and 4. Resistance to penetration, - on skid trails, bush landings and secondary forest are; 1.22, 17, 14 years; 2.24, 17, 15 years; 3.52, 37, 28 years; 4.19, 14, 12 years. Skid trails being the worst. E.g. mean bulk density linear drop from 1.65 to 1.5 after 1 or 11 yrs post logging (data for every year). Porosity increases from 49 to 51% in same period. Resistance to penetration from c. 420 to 270.

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Kalyakin, M. V., L.P. Korzun, & V.I.Trunov. 1994 On the biodiversity of birds in lowland tropical

forests of south Vietnam. Pp. 37-38 Zoologisches Forschungsinstitut und Museum Alexander Koenig (eds.) International Symposium on Biodiversity and Systematics in Tropical Ecosystems, Abstracts, Bonn, Germany.

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Kammesheidt, L., A.A. Dagnag, W. Schwarzwäller & H-J. Weidelt. 2003. Growth patterns of dipterocarp in treated and untreated plots Forest Ecology and Management 174: 437-464

Kammesheidt, L., P. Kohler, & A. Huth. 2002. Simulating logging scenarios in secondary forest embedded in a fragmented neotropical landscape. Forest Ecology and Management 170: 89-150

Karani, P. K. 1968. Flowering, fruiting and seeding habits of Uganda indigenous trees. Technical Note 156/68. Forestry Dept., Uganda.

Kariuki, M., R.M. Kooyman, R.G.B. Smith, G. Wardell-Johnson, & J.K. Vanclay. 2006. Regeneration changes in tree species abundance, diversity and structure in logged and unlogged subtropical rainforest over a 36-year period. Forest Ecology and Management 236: 162-176

Karsenty, A. & S. Gourlet-Fleury. 2006. Assessing sustainability of logging practices in the Congo Basin's managed forests: The issue of commercial species recovery. Ecology and Society 11:

Karsenty, A., I.G. Drigo, M.G. Piketty, & B. Singer. 2008. Regulating industrial forest concessions in Central Africa and South America. Forest Ecology and Management 256: 1498-1508

Kartawinata, K. 1979. An overview of the environmental consequences of tree removal from the forest in Indonesia. In Biological and Sociological bases for rational use of forest resources for energy and organics. USDA forestry services, Indonesia

Kartawinata, K., S. Adisoemarto, S. Riswan, & A.P. Vayda. 1981. The impact of man on tropical forest of Indonesia. Ambio 10: 115-119

Kartawinata, K. T.C. Jessup, & A.P. Vayda. 1989. Exploitation in Southeast Asia. Pp 591-610 in Leith, H., & M.J.A. Weger. (eds.) Tropical rainforest ecosystems Elsevier, Amsterdam. The Netherlands

Kasenene, J. M. 1984. The influence of selective logging on rodent populations and the regeneration of selected tree species in the Kibale Forest Reserve, Uganda. Journal of Tropical Ecology 25: 179-195.

Kasenene, J.M., 1987. The influence of mechanized selective logging, felling intensity and gap-size on the regeneration of a tropical moist forest in the Kibale Forest Reserve, Uganda. Ph.D. Dissertation. Michigan State University, Michigan.

Kasenene, J.M. 2007. Postlogging structural changes and regeneration of *Olea welwitschii* (Knobl) Gilg. & Schellemb. in the Kibale National Park, Uganda. African Journal of Ecology 45:109-115

Kasenene, J. M. & P. G. Murphy. 1991. Post-logging tree mortality and major branch loss in Kibale forest reserve, Uganda. Forest Ecology and management 46: 295-307.

A study of three compartments with different management history (control, light logging in 1969 ($14m^3$/ha extracted) and heavy logging in 1969 ($21m^3$/ha). Tree and large branch falls were censused over 20 consecutive months as visual estimates along trails (c. 7km long). Strip width estimated as twice the mean perpendicular distance of the observations. Standing trees estimated in 40 (5x20m) quadrats at 120m along the census routes. Rate of tree falls were estimates as 12Dmx100/ (20xDS) where Dm = mean monthly density of tree falls or dead standing trees and Ds = density susceptible trees per study area. 20 and 12 are the number of months of sampling and months/year. Only new tree/large branch falls were recorded.

In heavily logged forest more live than dead trees snapped off and were uprooted, whereas in the control, the converse was true. The density of canopy trees falling was not significantly different between cut and mature forest. Species composition of tree falls differed between the three compartments. All three samples showed two peaks of tree fall with size: between 21-50cm dbh and a larger peak between 60-80cm dbh. Heavily logged forest had the highest fall rate in the larger dbh band, followed by lightly logged forest. Hence, heavy selective felling changed the pattern of tree fall, with more live than dead trees falling. Mortality was 1.3 (heavy), 3.3 (light) and 1.74 (uncut) which corresponds to earlier studies. Small tree mortality may largely be a function of larger tree falls.

Kavanagh, R. P. 1991. The target species approach to wildlife management: gliders and owls in the forests of South-eastern New South Wales. Pp. 377-383.in Lunney, D. (ed.) Conservation of Australia's forest fauna Conservation of Australia's forest fauna, Mosman: Royal Zoological Society of New South Wales.

Kavanagh, R. P. & K.L, Bamkin, 1995. Distribution of nocturnal forest birds and mammals in relation to the logging mosaic in South-eastern New South Wales, Australia. Biological Conservation 71: 41-53.

Kavanagh, R. P., J.M. Shields, H.F. Recher, & W.G. Rohan-Jones, 1985. Bird populations of a logged and unlogged forest mosaic at Eden, New South Wales. Pp. 273-281 in Keast, A., H. F. Recher, H. Ford & D. Saunders, (eds.) Birds of eucalypt forests and woodlands: ecology, conservation, management. Sydney: Surrey Beaton and Sons.

Kasangaki, A., D. Babaasa, J. Efitre, A. McNeilage, & R. Bitariho. 2006. Links between anthropogenic perturbations and benthic macroinvertebrate assemblages in afromontane forest streams in Uganda. Hydrobiologia 563: 231-245

Keay, R. W. J. 1957. Wind-dispersed species in a Nigerian forest. Journal of Ecology 45: 471-478.

Taller trees were found to have higher incidence of wind-dispersal.

Keay, R. W. J. 1961. Increment in the Okomu forest, Benin. Nigerian Forestry Information Bulletin 34.

Keay, R. W. J. & F. N. Hepper (revisers for second edition). 1972. Flora of West Tropical Africa. Crown Agents, London.

Kemp, A. C. & M.I, Kemp. 1975. Report on a study of hornbills in Sarawak, with comments on their conservation. Final report to project 2/74, World Wildlife Fund Malaysia, Kuala Lumpur.

Kemp, N., M. Dilger, & L.M. Chan, 1995. Site description and conservation evaluation: Pu Mat Nature Reserve, Con Cuong District, Nghe An Province Vietnam. London, The Society for Environmental Exploration

Kemp, R. H. 1961. Growth and regeneration of *Khaya grandifoliola* in 'Kurame' in southern Zaria province. Dept. Forest Research Nigeria Technical Note 10.

Khaya g. was found to thrive on the margin between forest islands and savanna.

Kemp, R. H. , M. Flint, J. K. Vanclay. 1993. Forest Inventory and management project. Review and project preparation report. Unpublished. O. D. A. /Ghana Forestry Dept.

Reviews progress of the project, and steps needed for planning branch, and forest management in Ghana, to become efficient and scientifically based.

Kennard, D. K. 1998. Biomechanical properties of tree saplings and free-standing lianas as indicators of susceptibility to logging damage. Forest Ecology and Management 102: 179-191.

Liana infestations impede regeneration after selective logging in Sabah. Trees and lianas have similar flexibilty as saplings, resprouting abilities and suffer similar logging damage and subsequent mortality, hence liana tangles not the result of differential survival of trees and lianas.

Kennedy, D.N. & M.D. Swaine. 1992. Germination and growth of colonizing species in artificial gaps of different sizes in dipterocarp rainforest. Phil. Trans. Royal Soc. of London Series B

335:357-366

Colonising seedlings monitored for 3 yrs in lowland rainforest, Sabah, in newly made gaps and under primary forest. Germination not affected by gap size, but increased with soil exposure or disturbance. Diversity of regenerating vegetation was negatively related to gap size. Seedling mortality was less in large gaps and without competition from advance regeneration; opposite true for seedling growth. Gap size unlikely to influence colonising vegetation composition by controlling germination, but differential mortality may be important.

Khan, N.1995. Protection of North Selangor peat swamp forest, Malaysia. Parks 5: 24-31.

Kiama, D. & J. Kiyiapi. Shade tolerance and regeneration of some tree species of a tropical rain forest in Western Kenya. Plant Ecology 156:183-191

Kielland-Lund, J. 1982. Structure and morphology of four forest and woodland communities of the Morogoro area, Tanzania. *Struktur und Dynamik von Walden. Bericht des 25. Internationalen. Symposions der Internationalen Vereinigung fur vegetationskunde*.

Kigomo, B. N. , S. R. Woodell & P. S. Savill. 1994. Phenological patterns and some aspects of the reproductive biology of *Brachylaea huillensis* O. Hoffm. African Journal of Ecology 32: 296-307.

More males than females. 80% loss of fruit predispersal due to insects. 6% viability in forest; loss of viability accelerated by sunlight and soil organisms - complete loss in forest in 15 weeks. Sustained regeneration probably requires attention to balance of sexes.

Kim, J. , Y. Son, Z. Kim, J. S. Kim, Y. H. Son & Z. S. Kim. 1995. Allometry and canopy dynamics of Pinus rigida, Larix leptolepis, and Quercus serrata stands in Yangpyeong area. Journal of Korean Forestry Society 84: 186-197

King, D. A. 1981. Tree Dimensions: maximising the rate of height growth in dense stands. Oecologia 51: 351-356.

King, D. A. 1986. Tree form, heigh growth and susceptibility to wind damage in Acer saccharum. Ecology 67: 980-990.

King, D. A. 1990. Allometry of saplings and Understory trees of a Panamanian forest. Functional Ecology 4: 27-32.

The allometry of nderstory tree species (6 spp.) were contrasted with saplings of larger canopy trees in Panama. Smaller understory trees have thicker trunks and wider, heavier, leafier crowns than similar height (2-5m) saplings of canopy spp. Understory species are optimised for living there, unlike larger trees which are optimised for height growth.

King, D. A. 1991. Correlations between biomass allocation, relative growth rate and light environment in tropical forest saplings. Functional Ecology 5: 485-492

Nine species in Costa Rican wet forest. Gap-associated species allocate $^2/_3$ of above ground growth to the stem and branches under all measured conditions.

King, D. A. 1996. Allometry and life history of tropical trees. Journal of Tropical Ecology 12: 25-44.

14 common Costa Rican trees from wet lowland forest: relationship between crown size and trunk diameter. Adults of understory trees are larger-crowned than similar stature (6-15m) saplings of canopy trees; Species common in gaps as saplings are larger-crowned than shade-tolerant species when 1-6m high; long-lived canopy species show greater increases in crown breadth as height increase than shorter-lived trees. Related to, the need to withstand high winds in the upper canopy. DBH/height relations are shown to lie within mechanical constraints.

King, G. C. & W. S. Chapman. 1983. Floristic composition and structure of a rainforest area 25 years after logging. Australian Journal of Ecology 8: 415-423.

Forest might take 140-190 yrs to recover. After 25 yrs, a 7.8 ha area of logged forest which had had 90% of the canopy trees removed had recovered all plant species, but regrowth canopy was 12m rather than 35m tall.

Kinnaird M. F., E.W, Sanderson, T.G, O'Brien, H.T, Wibisono, & G. Woolmer. 2003. Deforestation trends in a tropical landscape and implications for endangered larger mammals. Conservation Biology 12: 245-956

Kira, T. 1978. Community architecture and organic matter dynamics in tropical lowland rain forests of Southeast Asia with special reference to Pasoh Forest, West Malaysia. Pp 561-590 in Tomlinson, P. B. & M. H. Zimmerman (eds.)

Hyperbolic (almost linear, than asymptote) relation between tree height and DBH. Height decreases with rainfall. Total wood biomass density decreases vertically in forest, but leaf biomass peaks at 1.3m and c. 25-35m.

Kirika, J.M., N.Farwig, & K. Bohning-Gaese. 2008. Effects of local disturbance of tropical forests on frugivores and seed removal of a small-seeded afrotropical tree. Conservation Biology. 22: 318-328

Kitajima, K. & C. K. Augspurger. 1989. Seed and seedling ecology of a monocarpic tropical tree, *Tachigalia versicolor*. Ecology 70: 1024-1114.

2 yr study on BCI, Panama. High seedling survival and abundant production associated with monocarpic fruiting.

Klein, B.C. 1989. Effects of Forest fragmentation on dung and carrion beetle communities in Central Amazonia. Ecology 70: 1715-1725

Kochumen, K. & F. S. P. Ng. 1977. Natural plant succession after farming at Kepong. The Malayan Forester 40: 61-78.

Recovery of forest had been delayed by dominance of *Gleichenia* fern and *Melastoma*, although trees were appearing after 30 years.

Koehler, P.; Huth, A.. 2010. Towards ground-truthing of spaceborne estimates of above-ground life biomass and leaf area index in tropical rain forests. *Biogeosciences* 7 (8)

Kofron, C.P. & A. Chapman. 1995. Deforestation and bird species composition in Liberia, West Africa. Tropical Zoology 8: 239-256

Koh, L.P. 2007. Impacts of land use change on South-east Asian forest butterflies: a review. Journal of Applied Ecology 44: 703-713

Kohyama, T. 1987. Significance of architecture and allometry in saplings. Functional Ecology 1: 399-404.

Nine common shade-tolerant saplings from lowland rain forest in Sumatra examined. Detected interspecific differences explained as a result of trade-off between height growth and area extension. Saplings of emergent favoured height growth.

Kohyama, T. 1991. A functional model describing sapling growth under a tropical forest canopy. Functional Ecology 5: 83-90.

Model based on published data on allometry of shade-tolerant saplings. Distinction between branch-developing and trunk developing saplings. The former have greater larger trunk diameter, wider crown area and lower leaf area density at the same height than trunk developing ones.

Kohyama, T. 1992. Size-structured multi-species model of rain forest trees. Functional Ecology 6: 206-212.

Kohyama, T. 1993. Size-structured tree populations in gap-dynamic forest - the forest architecture hypothesis for the stable co-existence of species. Journal of Ecology 81: 131-143.

Kohyama, T. & M. Hotta. 1990. Significance of allometry in tropical saplings. Functional Ecology 4: 515-521.

Nine species from West Sumatra, all 'shade-tolerant', but various maximum heights. Species were different in intercepts but not in the slope of log (dimensions). Emergent's saplings emphasised height growth rather than expansion of crown. Advantages of maintaining assimilative area at present height lower in a habitat with a steeper light gradient or higher growth rate like tropical forests.

Korem, A. 1985. *Bush fires and agricultural development in Ghana*. Ghana Publishing Corporation, Tema, Ghana.

Korning, J. & H. Balslev, 1994. Growth rates and mortality patterns of tropical lowland tree species and the relation to forest structure in Amazonian Ecuador. Journal of Tropical Ecology 10: 151-166

Kouadio, Y.L. & J.L. Doucet. 2009. Study of the behaviour of *Baillonella toxisperma Pierre* (moabi) in enriched logging gaps. Biotechnologie Agronomie Societe et Environment 13: 317-324

Krajicek, J. E. , K. A. Brinkman, & S. F. Gringrich. 1961. Crown competition - a measure of density. Forest Science 7: 35-42.

Kubota, Y. & T. Hara 1996. Allometry and competition between saplings of *Picea jezoensis* and *Abies sachalinensis* in a sub-boreal coniferous forest, northern Japan. Annals of Botany 77: 529-537

Kuerpick, P. , U. Kuerpick & A. Huth. The influence of logging on a Malaysian dipterocarp rain forest. A study using a forest gap model. Journal of theoretical Biology 185: 47-54.

Simulation of different logging techniques in gap-aware model on forest composition and logged biomass. With or without incidental damage to trees, the latter suggesting 100 years logging cycle to maximise yield, 200 years to restore species composition. 20 year cycles low yield and greater change in composition. Logging damage very important to take into account when modelling.

Kunisaki, T. & M. Imada 1996. DBH-height relationship for Japanese red pine (*Pinus densiflora*) in extensive natural forests in southern Japan. Journal of Forest Planning 2: 115-123

Kushawa S. P. S. , P. S. Ramakrishnan & R. S. Tripathi. 1981. Population dynamics of *Eupatorium odoratum* in successional environments following slash and burn agriculture. Journal of Applied Ecology 66: 247-295.

Kuuluvainen, T. 1991. Relationships between crown projected area and components of above-ground biomass in Norway spruce stands: empirical results and their interpretation. Forest Ecology and management 40: 243-260.

Kuusipalo, J., Y. Jafarsidik, G. Adjers, & K. Tuomela. 1996. Population dynamics of seedlings in a mixed dipterocarp rain-forest before and after logging and crown liberation. Forest Ecology and Management 81: 85-94

Kyereh, B. 1994. *Seed phenology and germination of Ghanaian forest trees*. PhD thesis. University of Aberdeen, U. K.

Kyereh, B. , M. D. Swaine & J. Thompson. 1999. Effect of light on the germination of forest trees in Ghana. Journal of Ecology 87: 772-783.

19 species of tree tested in various light qualities including full light and dark. Germination only reduced in dark for *Musanga*, *Nauclea* and *Milicia* (with smallest seeds, and spp. from the seedbank). Only subsets of pioneers are photoblastic – other species like *Terminalia* and R*icinodendron* can germinate in shade. Some disagreement between forest and shade-house (*Pericopsis* increased % germination in high light only in shade-house), probably due to drought in forest, where not watered. Oddly. *Ricinodendron* 42% germinates in dark, but zero in 2% light.

Lacoste, J. F. & D. Y. Alexandre. 1991. Kopi (*Goupia glabra*), a promising timber tree for forestry in French Guiana: a literature review. Annales des Sciences Forestieres 48: 429-441.

Review of ecology etc. of this fast growing pioneer in the neotropics, which rapidly colonises open areas and has straight stems and durable timber. Early removal of undesirable pioneer competition (*Cecropia, Vismia, Solanmum)* nevertheless useful in regrowth forests.

Lada, H., J.R. Thomson, R. Mac Nally, G. Horrocks, & A.C. Taylor. 2007. Evaluating simultaneous impacts of three anthropogenic effects on a floodplain-dwelling marsupial *Antechinus flavipes*. Biological Conservation 134: 527-536

Laidlaw, R. K. 1994. The Virgin Jungle Reserves of peninsular Malaysia: the ecology and dynamics of small protected areas in managed forest. PhD thesis. University of Cambridge, UK.

Laird, S. 1995. *The natural management of tropical forests for timber and non-timber products*. OFI-Occasional-Papers, No. 49. Oxford Forestry Institute, Oxford, UK.

Lamb, A. F. A. 1940. On the siviculture of Obeche. Nigerian Forester. 2: 15-20.

Lamb, D. 1990. Exploiting the tropical rain forest: an account of pulpwood logging in Papua New Guinea. Man and the Biosphere series. UNESCO & Parthenon.

The book as a whole explores clear-felling in Papua New Guinea. Chapter 5 explores environmental consequences in the Gogol valley. Normal patterns of regrowth of pioneers, where regenerating seedling densities are inversely proportional to soil disturbance. Animal, soil, water aspects are summarised in turn. 'Neither selective logging or clear-felling produced a dramatic hydrological impact'. Likewise sediment in rivers is naturally high, and logging effects therefore difficult to detect. The role of residual seedling is judged small; the soil seed bank is important for a few early pioneer species; vegetative regrowth may play a significant role in the re-establishment of logged forest, especially for 'large secondary' or primary forest species. Measured seed rain included no primary forest species, but many secondary forest ones. However, this was probably due to undersampling as primary forest species may arrive from elsewhere.

Lamb, D. 2011. *Regreening the Bare Hills: Tropical Forest Restoration in the Asia-Pacific Region*. Series: World Forests, Vol. 8, Springer, pp. 547.

Explores how reforestation might be carried out both to conserve biological diversity and to improve the livelihoods of the rural poor. Combines a theoretical-research perspective with practical aspects of restoration.

Lambert, F. R. 1992. The consequences of selective logging for Bornean lowland forest birds. Pp 443-457. in Marshall A. G. & M. D. Swaine (eds.) Tropical rain forest: disturbance and recovery, London: The Royal Society.

Lambert, F.R. & N.J. Collar. 2002. The future for Sundaic lowland forest birds: long-term effects of commercial logging and fragmentation. Forktail 18: 127-146

Lammertink, M. 2004. A multiple-site comparison of woodpecker communities in Bornean lowland and hill forests: effects of logging and conservation implications Conservation Biology 18: 746-757

Lammerts van Beuren, E. M. & J.F. Duivenvoorden. 1996. Towards priorities of biodiversity research in support of policy and management of tropical rainforests. Wageningen: The Tropenbos Foundation

Lancaster, P. C. 1954. *Khaya ivorensis* regeneration - interim observations. Nigerian Forestry Information Bulletin (August 1954).

Lancaster, P. C. 1961. Experiments with natural regeneration in the Omo forest reserve. Nigerian Forestry Information Bulletin 13: 5-16.

Laporte, N.T., J.A. Stabach, R. Grosch, T.S. Lin, & S.J. Goetz. 2007. Expansion of industrial logging in Central Africa. Science 316: 1451-1451

Regular monitoring with satellite remote sensing provides a consistent approach to monitor both legal and illegal logging activities. Industrial logging has become the most extensive land use in Central Africa, with more than 600,000 square kilometers (30%) of forest currently under concession. A new frontier of logging expansion was identified within the Democratic Republic of Congo, which contains 63% of the remaining forest of the region. Tree felling and skid trails increased disturbance in selectively logged areas.

Laurance, W.F. 1999. Reflections on the tropical deforestation crisis. Biodiversity and Conservation 91: 109-117

Laurance, W. F. 1991. Ecological correlates of extinction proneness in Australian tropical rain forest mammals. Conservation Biology 5: 79-89.

Laurance, W.F., A. Alonso, M. Lee, & P. Campbell. 2006. Challenges for forest conservation in Gabon, central Africa. Futures 38: 454-470

Laurance, W.F., B.M. Croes, N. Guissouegou, R. Buij, M. Dethier, & A. Alonso. 2008. Impacts of roads, hunting, and habitat alteration on nocturnal mammals in African rainforests. Conservation Biology 22: 721-732

Laurance, W.F., J.M. Fay, R.J. Parnell, G.P. Sounguet, A. Formia, & M.E. Lee. 2008. Does rainforest logging threaten marine turtles? Oryx 42: 246-251

Laurence, W. F. & S. G. W Laurence. 1996. Responses of five Arboreal Marsupials to recent selective logging in tropical Australia. Biotropica 28: 310-322.

Censuses were conducted of a diverse assemblage of folivorous marsupials over 1yr prior and 3yrs after logging. An average of 8-10 trees/ha were extracted. Two formerly logged sites were used as control. Lemuroid ringtail possums declined significantly while three other possums and a tree kangaroo were apparently not greatly affected. The amount of structural damage in logging would have the most effect on ecological and behavioural traits.

Laurance, W.F. & D.C. Useche. 2009. Environmental Synergisms and Extinctions of Tropical Species. Conservation Biology 23: 1427-1437

Laurance, WF; Camargo, JLC; Luizao, RCC; Laurance, SG; Pimm, SL; Bruna, EM; Stouffer, PC; Williamson, GB; Benitez-Malvido, J; Vasconcelos, HL; Van Houtan, KS; Zartman, CE; Boyle, SA; Didham, RK; Andrade, A; Lovejoy, TE. 2011. The fate of Amazonian forest fragments: A 32-year investigation. Biological Conservation 144: 56-67

Lawes, M.J., M.E. Griffiths, & S. Boudreau. 2007. Colonial logging and recent subsistence harvesting affect the composition and physiognomy of a podocarp dominated Afrotemperate forest. Forest Ecology and Management 247: 48-60

The impact of logging 100 years ago in South Africa can still be seen today because the understorey angiosperm-dominated species that regenerated in the logging gaps have subsequently been the focus of local subsistence harvesting of small DBH poles from the forest. The preferred, straight poles tend to be canopy species, and this pattern of use is preventing regeneration of the original Podocarp forest. Vegetation that is reduced stature, with thicket-like physiognomy, less diverse and less dominated by conifers is the expected successional outcome without intervention.

Lawes, M.J. & C.A. Chapman. 2006. Does the herb *Acanthus pubescens* and/or elephants suppress tree regeneration in disturbed Afrotropical forest? Forest Ecology and Management 221: 278-284

Lawes, M.J. & J.A.F. Obiri. 2003. Using the spatial grain of regeneration to select harvestable tree species in subtropical forest. Forest Ecology and Management 184: 105-114

Lawson, G. W. (ed.). 1986. Plant Ecology in West Africa. John Wiley & Sons Ltd.

Lawton, R. M. 1955. The relationship between crown form and sex in *Chlorophora excelsa*. Empire

Forestry Journal 34: 192-3.

Leakey, R. R. B. , N. R. Ferguson & K. A. Longman. 1981. Precocious flowering and reproductive biology of *Triplochiton scleroxylon* K. Schum. Commonwealth Forestry Review 60: 117-126

Lees, A.C. & C.A. Peres. 2006. Rapid avifaunal collapse along the Amazonian deforestation frontier. Biological Conservation 133: 198-211

Lee, H. S. 1982. The development of silvicultural systems in the hill forests of Malaysia. Malaysian Forester 45: 1-9.

Lee, S. S. & I. J. Alexander. 1996. The dynamics of ectomycorrhizal infection of *Shorea leprosula* seedlings in Malaysian rainforests. New Phytologist 132: 297-305

Lee, S. S. , I. J. Alexander, P. Moura-Costa & S. W. Yap. 1996. Mycorrhizal infection of dipterocarp seedlings in logged and undisturbed forest. Pp 157-164 in Appanah, S. & A. H. Khoo (eds.) Proceedings of the 6th round table conference on dipterocarps, Forest Research Institute of Malaysia, Kuala Lumpur.

Leech, J. W. 1984. Estimating crown width from diameter at breast height for open-grown radiata pine trees in South Australia. Australian Forest Research 14: 333-337.

Lehman, S. M., R.W. Sussman, J. Phillips-Conroy, & W. Prince. 2003. Ecological biogeography of primates in Guyana: The effects of natural and anthropogenic disturbances. American Journal of Primatology 60: 105-139

Leigh, E. G. Jr. , A. D. Rand & D. M. Windsor (eds.) 1982. The ecology of a tropical forest: seasonal rhythms and long-term changes. Smithsonian University Press. Washington DC.

Leighton, M. And D. R. Leighton. 1983. Vertebrate responses to fruiting seasonality within a Bornean rain forest: Pp 181-196. Sutton, in L. , T. C. Whitmore and A. C. Chadwick (eds.). Tropical Rain Forest: Ecology and management Blackwell Scientific, Oxford.

Leith, H. & M. Lohmann (eds.). 1993. Restoration of tropical forest ecosystems. Kluwer Academic, Dordrecht.

Letouzey, R. 1957. La foret a *Lophira alata* del la zone littorale camerounaise. Revue Bois et Forets des Tropiques 53: 9-20.

Discusses species, including *Lophira*, which are in some areas abundant but without evident regeneration. Proposes such patches may indicate earlier human settlement.

Lewis, O.T. 2001. Effect of experimental selective logging on tropical butterflies. Conservation. 15: 389-400

Li, M. , M. Lieberman & D. Lieberman. 1996. Seedling demography in undisturbed tropical wet forests Pp 285-314 in Marshall, A. G. & M. D. Swaine, (eds.) Tropical rain forest: disturbance and recovery, London: The Royal Society.

Mortality of young seedings varies (decreases) with age.

Lieberman, D. 1979. Dynamics of forest and thicket vegetation on the Accra Plains, Ghana. PhD thesis. University of Ghana.

Lieberman, D. 1982. Seasonality and phenology in a dry tropical forest in Ghana. Journal of Ecology 70: 791-806.

Lieberman, D. 1996. Demography of tropical tree seedlings: a review. Pp 131-138. Marshall, A. G. & M. D. Swaine,(eds.) Tropical rain forest: disturbance and recovery, London: The Royal Society.

Summary of previous work.

Lieberman, D. & M. Li. 1992. Seedling recruitment patterns in a tropical dry forest in Ghana. Journal

of Vegetation Science 3: 375-382.

Liberman, M. & D. Lieberman. 1985. Simulation of growth curves from periodic increment data. Ecology 66: 632-635

Liberman, M. & D. Lieberman. 1987. Forest tree growth and dynamics at La Selva, Costa Rica. Journal of Tropical Ecology 3: 347-359

Lieberman, D. , M. Lieberman, G. Hartshorn & R. Peralta. 1985a. Growth rates and age-size relationships of tropical wet forest trees in Costa Rica. Journal of Tropical Ecology 1: 97-109.

Lieberman, D. , M. Lieberman, R. Peralta & G. S. Hartshorn. 1985b. Mortality patterns and stand turnover rates in a wet tropical forest in Costa Rica. Journal of Ecology 73: 915-924

Lieberman, M. , D. Lieberman & R. Peralta. 1989. Forests are not just Swiss cheese: canopy stereogeometry of non-gaps in tropical forests. Ecology 70: 550-552.

Suggests the gap vs. non-gap paradigm is misleading, and studies should rather concentrate on a more dendrocentric approach, by using canopy closure indices.

Lieberman, M. , D. Lieberman, R. Peralta & G. S. Hartshorn. 1995. Canopy closure and the distribution of tropical forest tree species at La Selva, Costa Rica. Journal of Tropical Ecology 11: 161-178.

Index of canopy closure above the crowns of all trees >= 10cm dbh in 11 ha. undisturbed rain forest. Analyses for 104 species with >=6 individuals. 9 species in more open places, 5 in more closed species, 90 species at random with respect to canopy closure. Tree height estimated from tree size when calculating closure (Ht=5. 5 x dbh $^{2/3}$). Index of canopy closure for each tree =Σ sin θ for all trees in 10m, where θ=difference in ht/h: h=(hypotenuse) distance between tops of two trees.

Liebsch, D., Marques, M., Goldenbeg, R., 2009. How long does the Atlantic Rain forest take to recover after a disturbance? Changes in species composition and ecological features during secondary succession. Biological Conservation 141: 1717–1725.

Liew, T. C. 1973. The practicability of climber cutting and tree marking prior to logging as a silivicultural tool in the management of dipterocarp forest in Sabah. The Malaysian Forester 36: 80-122.

Climbers (vines) increase felling damage during logging. Discusses practicability of getting rid of them. Maps and tables show distribution of pole-sized trees in compt 45 Umas Umas F. R. Types of damage are also categorised. 70% of pole-sized trees suffered some damage after treatment. Recommendations for improved logging are: restriction of landings (loading bays) and numbers of paths (skid trails); retention of seed-bearers; climber cutting of selected stems before logging

Liew, T. C. & F. O. Wong. 1973. Density, recruitment, mortality and growth of dipterocarp seedlings in virgin and logged-over forests in Sabah. The Malaysian Forester 36: 3-15.

Lima, A.P., F.I.O. Suarez, & N. Higuchi. 2001. The effects of selective logging on the lizards *Kentropyx calcarata*, *Ameiva ameiva* and *Mabuya nigropunctata*. Amphibia-Reptilia 22: 209-216

Lindenmayer, D. B. 1992. Some impacts on arboreal marsupials of clear felling on a 80-120 year rotation in Mountain Ash *Eucalyptus regnans* forests in the central highlands of Victoria. Victorian Naturalist 109: 181-186.

Lindenmayer, D. B., R.B. Cunningham & C.F. Donnelly. 1993. The conservation of arboreal marsupials in the montane ash forests of the Central Highlands of Victoria, South-east Australia, IV. The presence and abundance of arboreal marsupials in retained linear habitats (wildlife corridors) within logged forest. Biological Conservation 66: 207-221.

Lindenmayer, D. B., R.B. Cunningham, M.T. Tanton, H. Nix & A.P. Smith. 1991. The conservation of arboreal marsupials in the montane ash forests of the Central Highlands of Victoria, southeast Australia, III. The habitat requirements of Leadbeater's possum *Gymnobelideus leadbeateri* and models of the diversity and abundance of arboreal marsupials. Biological Conservation 56: 295-315.

Lindenmayer, D.B., J.F. Franklin, & J. Fischer. 2006. General management principles and a checklist of strategies to guide forest biodiversity conservation. Biological Conservation 131: 433-445

Warns against using shortcuts such as indicator species, focal species and threshold levels for guiding conservation efforts due to high variability between sites, species, landscapes, regions and forest types and unclear relationships between such proxies and what is actually of interest. Proposes broadly applicable guiding principles instead, including (1) the maintenance of connectivity; (2) the maintenance of landscape heterogeneity; (3) the maintenance of stand structural complexity; and (4) the maintenance of aquatic ecosystem integrity; (5) the use of natural disturbance regimes to guide human disturbance regimes.

Lindenmayer, D.B., McCarthy, M.A., 2002. Congruence between natural and human forest disturbance – an Australian perspective. Forest Ecology and Management 155: 319–335.

Lindenmayer, D.B. & R.F. Noss. 2006. Salvage logging, ecosystem processes, and biodiversity conservation. Conservation Biology 20: 949-958

Discusses the impacts of salvage logging, where trunks are recovered following natural disturbance. Can be negative, positive or neutral; additional to or different from the effects of traditional logging, and depend on initial circumstances.

Lindenmayer, DB. 2010. Landscape change and the science of biodiversity conservation in tropical forests: A view from the temperate world. Biological Conservation 143: 2405-2411

Lindner, A. 2009. A rapid assessment approach on soil seed banks of Atlantic forest sites with different disturbance history in Rio de Janeiro, Brazil. Ecological Engineering 35: 829-835

Lindsell, JA; Klop, E; Siaka, AM. 2011. The impact of civil war on forest wildlife in West Africa: mammals in Gola Forest, Sierra Leone. Oryx 45: 69-77

Linkie, M., W.A. Haidir, A. Nugroho, & Y. Dinata. 2008. Conserving tigers *Panthera tigris* in selectively logged Sumatran forests. Biological Conservation 141: 2410-2415

Loetsch, F. & K. E. Haller, 1973. *Forest Inventory.* vol. 1. Springer-Verlag, Berlin. 436 pp.

Logan, W. E. M. 1946. The Gold Coast Forestry Dept 1908-1945. Empire Forestry Review 25: 52-59.

Loiselle, B. A. , E. Ribbens, & O. Vargas. 1996. Spatial and temporal variation of seed rain in a tropical lowland wet forest. Biotropica 28: 82-95.

Seed rain compared in tree fall gaps and paired understory sites in NE Costa Rica. Seed rain mainly animal dispersed species. Greater total seed rain in understory, but more wind-dispersed seeds found to fall in gaps than understory.

Lonsdale, W. M. 1990. The self-thinning rule: dead or alive. Ecology 71: 1373-1388.

Concludes that one of ecology's more supported 'rules', relating plant size to density, is not very reliable.

Lopes, M. A. & S. F. Ferrari. 1994. Differential recruitment of *Eschweleira albiflora* (Lecythidaceae) seedlings at two sites in Western Brazilian Amazonia. Journal of Tropical Ecology 35: 25-34.

In older growth forest with more abundant parents, seedlings were less abundant and less vigorous than in younger (30 yr) forest (adults 25-33% common). Seed predation e.g. white uacari, probably important factor.

Loubry, D. 1993. *Dicorynia guianensis*: seed dispersal and seed parasitism before dipersal of a wind-dispersed tree in French Guiana. Revue d'Ecologie de la terre et la Vie 48: 353-363.

Emergent *Dicorynia guianensis* with wind-dispersed fruits, with seed scattered only to 30m from parent.

Lovett, J.C., R. Marchant, J. Taplin, & W. Kuper. 2005. The oldest rainforests in Africa: stability or resilience for survival and diversity? Phylogeny and Conservation 8: 198-229

Lowe, R. G. 1973. Silvicutural characteristics of trees in growth plots by pattern analysis and stand curve analysis on the (I. B. M. 1620) electronic computer. Research Paper Forest Series. Federal Department of Forest Research, Nigeria. 14.

Lowe, R. G. 1978. Experience with the shelterwood system of regeneration in natural forest in Nigeria. Forest Ecology and Management 1: 193-212.

Lowe, R. G. 1984. The regeneration and growth of ABURA: *Mitragyna stipulosa* (DC) O. Kuntze and *Mitragyna ciliata* Aubr. & Pellegr. Fed. Dept. of Forest Research, Ibaden. Technical Note 27.

Lowe, R. G. 1997. Volume increment of natural moist tropical forest in Nigeria. Commonwealth Forestry Review 76: 107-113.

Long thin PSPS (250x40m) with centre line demarcated; trees >5cm were measured. 5m^3/ha growth increment, 'therefore' THF can withstand removals of 50m^3/ha every 25 years. Trees on steep slopes benefit from side light hence plot increment more correlated with superficial not horizontally projected area. No correlation with standing volume, in spite of previous log removals.

Lowe, R. G. & P. Walker. 1977. Classification of canopy, stem crown status and climber infestation in natural tropical forests in Nigeria. Journal of Applied Ecology 14: 897-903.

Loyn, R. H. 1980. Bird populations in a mixed eucalyptus forest used for production of wood in Gippsland, Victoria. Emu 80: 145-156.

Loyn, R. H. 1985. Strategies for conserving wildlife in commercially productive eucalypt forest. Australian Forester 48: 95-101.

Loyn, R. H., M.A. MacFarlane, E.A. Chesterfield & J.A. Harris. 1980. Forest utilisation and the flora and fauna in Boola Boola State Forest in south-eastern Victoria. Forestry Commission of Victoria Bulletin 28: 1-80.

Loyn, R. H., P.C. Fagg. & J.E. Piggin. 1983. Changes in the composition of Understory vegetation after harvesting eucalypts for sawlogs and pulpwood in East Gippsland. Australian Journal of Ecology 8: 43-53.

LTS. 1995. Third Annual report for the Barama Company Ltd. , North West Guyana sustainable timber production programme (1. 1. 95-21. 12. 95). unpublished. LTS International, Edinburgh Centre for Tropical Forests.

Includes a summary of logging damage and gap sizes caused by logging in 15 PSPs. 20% of trees were felled or damaged. 5. 5% of BA is felled, causing 18.5% damage. Types of damage are tabulated.

Luna, A. C. , A. F. Gascon, R. D. Lasco, A. M. Palijon & M. L. Castillio. 1999. The community structure of a logged-over tropical rain forest in Mt. Makiling Forest Reserve, Philippines. Journal of Tropical Forest Science 11: 446-458.

4 ha. sample of forest selectively logged 50 years ago; high species diversity and complex guild structure. Species diversity indices normal for old growth of this type of forest; with primarily shade-tolerant species. However, low number of dipterocarps, which were originally dominant. Guilds were in terms of high or low shade-tolerance of canopy and non-canopy trees.

Lunney, D. & E. Ashby, 1987. Population changes in *Sminthopsis leucopus* (Gray) (Marsupalia: Dasyuridae) and other small mammal species, in forest regenerating from logging and fire near Bega, NSW. Australian Wildlife Research 14: 275-284.

Lunney, D. & J. Barker. 1987. Effects of logging, fires and drought on possums and gliders in the coastal forests near Bega, N.S.W. Australian Wildlife Research 14: 263-274.

Lunney, D., A. Matthews, P. Eby, & A.M. Penn. 2009. The long-term effects of logging for woodchips on small mammal populations .Wildlife Research 36: 691-701

Lunney, D. & M. O'Connell. 1988. Habitat selection by the swamp wallaby, *Wallabia bicolor*, the red-necked wallaby, *Macropus rufogriseus*, and the common wombat, *Vambatus ursinus*, in logged, burnt forest near Bega, New South Wales. Australian Wildlife Research 15: 695-706.

Lunney, D., J. Barker, & D. Priddel. 1985. Movements and day roosts of the chocolate wattled bat *Chalinolobus morio* (Gray) (Microchiroptera: Vespertilionidae) in a logged forest. Australian Mammalogy 11: 167-169.

Lunney, D., P. Eby, & M. O'Connell. 1991. Effects of logging, fire and drought on three species of lizards in Mumbulla State Forest on the south coast of New South Wales. Australian Journal of Ecology 16: 33-46

Mac Donagh, P; Rivero, L; Garibaldi, J; Alvez, M; Cortez, P; Marek, M; Erbetta, D; Fernandez, R; Phar, N; Toma, T. 2010. Effects of selective harvesting on traffic pattern and soil compaction in a subtropical forest in Guarani, Misiones, Argentine. Scientia Forestalis 38: 115-124

Macgregor, W. D. 1954. Silivicultural notes on *Mansonia altissima*. Empire Forestry Journal 33: 235-238.

Mackenzie, J. A. 1959. Phenology of *Triplochiton*. Dept. Forest Research, Nigeria Technical Note 1.

Macpherson, AJ; Schulze, MD; Carter, DR; Vidal, E. 2010. A Model for comparing reduced impact logging with conventional logging for an Eastern Amazonian Forest. Forest Ecology and Management 260: 2002-2011

Maginnis, S. 1994. Understory condition scoring of Ghanaian lowland tropical moist forest during stock survey: a technique for regulating the allowable cut in ecologically and structurally degraded production forest. Forest Ecology and management: 70: 89-97.

Recommends scoring forest condition every c.30m, summarising pioneer dominance of the understory, to help improve stock survey.

Magnusson, W. E., O. P. De Lima, F. Q. Reis, N. Higuchi, & J. F. Ramos. 1999. Logging activity and tree regeneration in an Amazonian forest. Forest Ecology and Management 113: 67-74.

Logging loss of 44-107 m^3/ha with 63% of this felled and only 43% removed. Manaus, 4 ha plots. Density of trees <10 cm DBH greater in logged plots 3 and 7-8 years after logging. Total potential value of regeneration 23% greater in logged plots, though not significant. Recommends enrichment planting.

Maillard, P. , M. Jaques, E. Miginiac, & R. Jaques. 1987. Growth of young *Terminalia superba* plants in controlled conditions. Annales des Sciences Forestieres 64: 67-83.

Maillard, P. , M. Jaques, E. Miginiac, & B. Millet. 1989. Mathematical growth analysis of young *Terminalia superba* plants in a controlled environment: comparison of growth rhythms of the principle axis and axillary branches. Annals of Botany 44: 95-10.

Maitre, H. F. 1986. Growth and yield of natural stands in the tropical rain-forests of Africa. Revue Bois et Forets des Tropiques 213: 13-20.

Description of three sets of silvicultural trials established by Sodefor in 1976 in the Ivory Coast. Blocks of 400ha were divided into 25x16 ha plots; each plot was treated throughout, with measurements on 10 cm dbh trees (70 commercial species only named; but others counted) in the central 4 ha. The same type of trial was repeated in three types of forest (Irobo-evergreen; La Tene-semideciduous; Mopri-transition). In each block, 30 were untouched; 35 were thinned by killing non-commercials (40% or 30% BA); 10 in La Tene only were exploited for all principal species >=80cm dbh (av. 53 m^3/ha). 2-10cm dbh trees recorded in 40 (10x10m) subplots in each plot. 48000 trees, renumerated every 2 years. The third set of data is summarised. Thinning leads to 50-100% greater dbh increment of commercials, especially for medium-sized stems. Dendrographs show accelerated diameter growth is progressively more pronounced.

Recruitment to 10cm+ over the four observation years is greatly enhanced. Logging is not as beneficial to the remaining commercials as thinning but much better than the controls. Similar BA is removed, but more heterogeneous. No clear effect on mortality is noted, but 2-10cm plants hardly changed by thinning. 16% of trees counted were of species likely to exceed 40 cm dbh.

Maitre, H. F. , 1991. Silvicultural interventions and their effects on forest dynamics and production in some rain forests of Cote D'Ivoire Pp 383-392. In Rain forest regeneration and management Pp 393-405. Gomez-Pompa, A., T.C. Whitmore and M. Hadley, (eds.). Man and the biosphere series, Vol. 6. UNESCO Paris.

A similar summary to the previous. MAI for *Khaya anthotheca* =0.2 (10-25cm trees) to 0.61 (25-65 cm), increasing slightly where thinned. Mortality around 4. 1% over 4 yrs. *Triplochiton* MAI=0.6-0.79 (control); 1. 53-1. 48 (thinned); 0.87-1.13 (harvested blocks) with mortality for 4 year period 2. 8-1. 5/2. 5/1. 4. 5. 7/2. 8. Treatment by exploitation increases volume production, but not as much as thinning, because harvesting produces irregular gaps, with poorly distributed large holes. Most benefit due to more active growth of small and medium trees. Doubling of production due to treatment (extra 270m3/ha, of which about half is 'principal species').

Makana, J.R., & S.C. Thomas. 2005. Effects of light gaps and litter removal on the seedling performance of six African timber species. Biotropica 37: 227-237

Makana, J.R., & S.C. Thomas. 2006. Impacts of selective logging and agricultural clearing on forest structure, floristic composition and diversity, and timber tree regeneration in the Ituri Forest, Democratic Republic of Congo. Biological Conservation 15: 1375-1397

Secondary forests growing after the initial clearing of primary forests for shifting cultivation show surprisingly high levels of tree species diversity (Shannon Weiner) for small stem sizes. Overall diversity measures of trees <1 cm dbh were similar between secondary and primary forest stands. However, notwithstanding the similarity in overall tree diversity, the floristic compositions of the two forest types were very different. Secondary forest was particularly depauperate in common species characteristic of old-growth forests in the region, particularly G. dewevrei and J. seretii, and understory specialists such as S. dewevrei, Drypetes spp. Rinorea spp., and Pancovia harmsiana. In this respect, our results corroborate those of other studies on tropical forest succession.

Malcom, J.R. & J.C. Ray. 2000. Influence of timber extraction routes on Central African small mammal communities, forest structure and tree diversity. Conservation Biology 14: 1623-1638

Mallory, E. P. & N.V.L. Brokaw. 1996. Impacts of Birds silvicultural trials on birds and tree regeneration in the Chiquibul Forest Reserve. Consultant report no. 20, Forest Planning and Management Project, Ministry of Natural resources, Belmopan, Belize.

Malvas, J. D. Jr. 1987. Development of forest sector planning, Malaysia. A report on the logging demonstration cum training coupe. UNDP/FAO Field Document MAL/85/004, no. 7.

Manokaran, N. , & K. M. Kochumen. 1987. Recruitment, growth and mortality of tree species in a lowland dipterocarp forest in Peninsular Malaysia. Journal of Tropical Ecology 3: 315-330.

Marcello, H. B. & E. T. Tagudar. 1956. Residual stands in selective high-lead logging. Philippines Journal of Forestry 123: 101-116.

Marn, H. 1982. The planning and design of the forest harvesting and log transport operation in the mixed dipterocarp forest of Sarawak. UNDP/FAO Field Document MAL/76/008, No. 7. Pp 76 (

Marn, H. & W. Jonkers. 1981. Logging damage in tropical high forest. Forestry Development Project

Sarawak. FAO FP:MAL/76/008, working paper 5. Kuching, Sarawak.

Results discussed from two studies carried out in mixed dipterocarp forest, Sarawak. In first, efficiency of current logging compared with one directed at minimising damage and reducing costs (directional felling, planning of skid trails). Directional felling in herring bone pattern, avoiding being perpendicular to skid trails. Main skid trails and landings were mapped (1:3000) with 'map showing concentrations of commercial trees'. Main trails as close as possible to denser stands of timber, ideally parallel to each other and perpendicular to main road, yet on a favourable grade. Where trees were evenly distributed, trails spacing=100-150m; however terrain sometimes overruled. Secondary skid trails were <50m long, located ad hoc., but carried as many logs to main trail as possible and 45° to 90° from main trail where possible. Damage was halved, efficiency increased by 36%, and costs were not increased. Damage measured over 2.4 ha. in each block 6 months after logging. c. 56/137 trees were damaged or broken in RIL, compared with c. 75/150 in the control. In second study, data analysed for three intensities (10, 32 and 55 m^3/ha, equivalent to about 2-3 trees, 6-7 trees and >13 trees / ha). Area occupied by skid trail and landings was 'virtually the same' although 'there are some indications that the area occupied by temporary open space increases with intensity'. Open space increased 5%, 9.4%, and 30.4%. 'All open areas' (= bare soil + open space) increased 12.9%, 22. %, and 40.8%. In the traditional logging, 27.5% of the area was opened. The results are compatible with earlier results of Nicholson (1958).

Marn, H. M. & W. Jonkers. 1982. Logging damage in tropical high forest. Pp 27-38 in Srivastava, P.B.L., A.M. Ahmad, K. Awang, A. Muktar, R.A. Kader, F.C. Yom & L.S. See (eds.) Tropical forests, source of energy through optimisation and diversification Serdang; Universiti Pertanian Malaysia.

Operations preceded by comprehensive planning had fewer accidents; fewer timber trees left unfelled; and fewer logs lost after felling. Also operations cost 20-45% less than comparable operations with minimal planning.

Marcot, B. G., R. E Gullison, & J.R. Barborak. 2001. The effects of logging on tropical forest ungulates in Fimbel, R.A., A. Grajal & J.G Robinson (eds.) The cutting edge: conserving wildlife in logged tropical forest. Columbia University Press New York USA

Marsden, S.J. 1998. Changes in bird abundance following selective logging on Seram, Indonesia. Conservation Biology 12: 605-611

Marsh, C. W. & W.L. Wilson. 1981. A survey of primates in peninsular Malaysian forests. Kuala Lumpur: Universiti Kebangsaan Malaysia

Marsh, C. W., A.D. Johns & J.M. Ayres. 1987. Effects of habitat disturbance on rain forest primates. Pp. 83-107. in Marsh, W.C & R.A. Mittermeier (eds.) Primate conservation in the tropical rain forest, New York: Alan R. Liss Incorporated.

Marshall, A. G. & M. D. Swaine (eds.). 1992. Tropical rain forest: disturbance and recovery. The Royal Society. London. 457 pp.

Symposium volume, compiling papers on the Royal Societies S. E. Asian programme on forest recovery after disturbance. Several studies on different aspects; including animals, soils, plants. See Kennedy and Swaine (1992).

Martin, C. 1991. The rainforests of West Africa; ecology, threats, conservation. Basel: Birkhauser Verlag.

Martin-Smith, K.M. 1998. Effects of disturbance caused by selective timber extraction on fish communities in Sabah, Malaysia. Environmental Biology of Fishes 53: 155-167

Martinez-Ramos, M. , A. Soto Castro, T. H. Fleming & A. Estrada. 1993. Seed rain and advanced regeneration in a tropical rain forest. Vegetatio 107: 299-318.

Seed rain, seedling and sapling communities compared. 50% of species entering 5 (25x25m) plots during one year came from fruiting trees within sites. Lianes and emergent trees were bias amongst immigrants.

Martinez-Ramos, M. & K. C. Samper. 1998. Tree life history patterns and forest dynamics: a conceptual model for the study of plant demography in patchy enviornments. Journal of Sustainable Forestry 6: 85-125

Los Tuxtlas. All stages of a plant's life cycle should be taken into account for ecological groups. Matrix approach included transitions between forest phase and tree life phase.

Martins, E. P. , A. D. de Oliveira, J. R. S. Scolforo, & A. D. De Oliveira. 1997. Evaluation of damage caused by forest exploitation to the remaining vegetation in natural forests. Cerne 3: 14-24.

Trees ≥10cm DBH mapped before logging, Rondonia, Brazil. 98 trees/ha damaged (22. 9%), mostly during tree felling.

Mason, D. J. 1996a. Responses of Venezuelan Understory birds to selective logging, enrichment strips and vine cutting. Biotropica 28: 296-309.

Mason, D. J. 1996b. Conserving birds in logged tropical forests: The value of riparian areas. Bulletin of the Ecological Society of America 77: 286

Mason, D.J. & F.E. Putz. 2001. Reducing the impacts of tropical forestry on wildlife Pp 473-509 in Fimbel, R.A., A. Grajal & J.G Robinson (eds.) The cutting edge: conserving wildlife in logged tropical forest. Columbia University Press New York USA.

Massimino, D., S. Masin, L. Bani, C. Dranzoa, & R. Massa. 2008. Partial recovery of an African rainforest bird community 35 years after logging. Ethology, Ecology and Evolution 20: 391-399

Mathews, A., & A. Mathews, 2002. Distribution, population density and status of sympatric cercopithecids in Campo-Ma'an area. South western Cameroon. Primates 43: 155-168

Matthews, A. & A. Matthews. 2006. Inventory of large and medium-sized mammals in south-western Cameroon. Mammalia 70: 276-287

Matveinen-Huju, K., J. Niemela, H. Rita, & R.B. O'Hara. 2006. Retention-tree groups in clear-cuts: Do they constitute 'life-boats' for spiders and carabids? Forest Ecology and Management 230: 119-135

Mayaux, P., P. Holmgren, F. Achard, H. Eva, H. Stibig, & A. Branthomme. 2005. Tropical forest cover change in the 1990s and options for future monitoring. Philosophical Transactions of the Royal Society B 360: 373-384

Mazzei, L; Sist, P; Ruschel, A; Putz, FE; Marco, P; Pena, W; Ferreira, JER. 2010. Above-ground biomass dynamics after reduced-impact logging in the Eastern Amazon. Forest Ecology and Management 259: 367-373

McIlroy, J. C. 1978. The effects of forestry practice on wildlife in Australia: a review. Australian Forestry, 41: 78-94.

McNabb, K. L. , M. S. Miller, B. G. Lockaby, B. J. Stokes, R. G. Clawson, J. A. Stanturf, J. N. M. Silva. 1997. Selection harvests in Amazonian rainforests: long-term impacts on soil properties. Forest Ecology and management 93: 153-160.

Surface soils were compared (pH, N, C, P,K, Ca, Mg, bulk density) across selection harvest study sites established in 1979. Concentrations of all elements displayed residual effects 16 yrs after harvest, with N, P, K, C inversely related to harvest intensity with Ca, Mg and pH directly related. Higher levels prior disturbance was still associated with increased bulk density. Effects were due to direct effects (bulk density) and indirect effects such as *Cecropia* sp. abundance.

Medjibe, V. & J.S. Hall. 2002. Seed dispersal and its implications for silviculture of African mahogany (Entandrophragma spp.) in undisturbed forest in the Central African Republic. Forest Ecology and Management 170: 249-257

Meijaard, E., D. Shiel, R. Nasi, D. Augeri, B. Rosenbaum, D. Iskandar, T. Setyawati, M. Lammertink, I.

Rachmatika, A. Wong, T. Soehartono, S. Stanley & T. O'Brien. Bogor, Indonesia: CIFOR 2005, 345 pp.

Meijaard, E., D. Sheil, R. Nasi, & S. A. Stanley. 2006. Wildlife conservation in Bornean timber concessions Ecology and Society 11:47

Meijer, W. 1970. Regeneration of tropical lowand forest in Sabah, Malaysia, forty years after logging. The Malaysian Forester 33: 204-229.

In 40 years after intensive logging, soil conditions had returned to before-logging condition. Complete floristic recovery had occurred, however structure had not been restored.

Mergen, F. , & R. Vincent. 1987. Natural management of tropical moist forests. Silvicultural and management prospects of sustained utilisation. Yale University. New Haven.

Mertens, B., E. Forni, & E.F. Lambin. 2001. Prediction of the impact of logging activities on forest cover: A case-study in the East province of Cameroon. Journal Environmental Management 62:21-36

Mervart, J. 1972. Growth and mortality rates in the natural high forest of western Nigeria. Nigerian Forest Information Bulletin (New series) 22.

For a given species and size, variation in increment is very high (coefficient of variation usually 60%). Stand table projection by average time of passage are erroneous. Present and past increment associated over short periods. With 2 ft girth classes, effects are practically non-existent. There is still some contribution to variance from species. Estimates of mortality from short time periods are unsuitable for predicting longer term losses, due to variation with time. Retarded trees die out fast. Fast growing species have slightly lower mortality losses than slow growing species over the same period of time. Different species showed different peaks of MAI with respect to DBH.

Migunga, G. A. 1995. Tropical forest soil compaction: effects of multiple log skidding tractor passes on surface soil bulk density at Sao Hill, Tanzania. Abstract: Proc 10 IUFRO world congress. 223.

Soil bulk density (0-15cm depth) of plantation forest soils increases. 87 -> 1.16 gm/cc after 5 passes, to 1.36 gm/cc after 10 passes of a farm tractor; and . 87->1. 53->1. 58 gm/cc with an articulated skidder. Most compaction occurs within the first 5 passes.

Miranda, MV; Politi, N; Rivera, LO. 2010. Unexpected changes in the bird assemblage in areas under selective logging in piedmont forest in northwestern Argentina. Ornitologia neotropical 21: 323-337

Missa, O., Y. Basset, A. Alonso, S.E. Miller, G. Curletti, M. De Meyer, C. Eardley, M.W. Mansell, & T. Wagner. 2009. Monitoring arthropods in a tropical landscape: relative effects of sampling methods and habitat types on trap catches. Journal of Insect Conservation. 13: 103-118

Mistry, S. 1998. Large scale patterns of seed dispersal. 1998. In Forest biodiversity research, monitoring and modelling. Conceptual background and old world case studies. P p 197-219 Man and the Biosphere series Vol. 20. UNESCO, Paris & Parthenon.

Dispersal modes bird, bat, (small and large) mammal, water, wind in Indian deciduous forest: largely abiotic dispersal . Declines with rainfall for 9 global sites (none African).

Mistry, J., M. Simpson, A. Berardi, & Y. Sandy, 2004. Exploring the links between natural resource use and biophysical status in the waterways of the North Rupununi, Guyana. Journal of Environmental Management 72:117-131

Miller, T. B. 1981. Growth and yields of logged over mixed dipterocarp forest in East Kalimantan. The Malaysian Forester 44: 419-424.

Net growth rate per hectare is inversely related to % trees cut, damaged or destroyed per unit area. Un-damaged trees of logged forest grow significantly faster than in 'virgin forest'. Some

areas will have replaced the volume removed in less than five years, but in other areas regrowth will take considerably longer than 40 years.

Moeur, M. 1993. Characterising spatial patterns of trees using stem-mapped dara. Forest Science 39: 756-775

Discussion of Hamill & Wright (1986) Nearest neighbour analysis, and a more comprehensive statistic 'Ripley's K(d) function which uses distances between all pairs of trees.

Morgan, D., C. Sanz, J.R. Onononga, & S. Strindberg. 2006. Ape abundance and habitat use in the Goualougo Triangle, Republic of Congo. International Journal of Primatology 27: 147-179

Morton, DC; DeFries, RS; Nagol, J; Souza, CM; Kasischke, ES; Hurtt, GC; Dubayah, R. 2011. Mapping canopy damage from understory fires in Amazon forests using annual time series of Landsat and MODIS data. Remote Sensing of Environment 115: 1706-1720

Mucunguzi, P. 2007. Diversity and distribution of epiphytic ferns in Kibale National Park, Uganda. Selbyana 28: 154-160

Muhanguzi, H.D.R., J. Obua, & H. Oryem-Origa. 2007. The effect of human disturbance on tree species composition and demographic structure in Kalinzu Forest Reserve, Uganda. African Journal of Ecology 45: 2-10

Reports abundance, spatial and size-class distributions of 10 species in mechanically logged, intensively pitsawn and minimally disturbed areas.

Muganga, J. L. L. 1989. Population dynamics micro-distribution of small mammals in the Kibale Forest Reserve, Uganda. M.Sc dissertation, Makerere University, Kampala.

Munang, M. 1987. Deforestation and logging. Pp 31-40. in Sani S. (ed.) Environmental conservation in Sabah, Kota Kinabalu, Sabah, Malaysia: Institute for Development Studies.

Murray, K. G. 1988. Avian seed dispersal of three neotropical gap-dependent plants. Ecological Monograpphs 58: 271-298.

Murua, R. & L. A. Gonzalez. 1985. Seed production of tree species in the rain forest of Valdivia. Bosque 6: 15-23.

Collecting box method, 1980-1983. Peak fruit production in Chilean summer and autumn.

Musamali, P. B. 1996. The effects of selective logging on the rodent community in the Budongo Forest, Reserve, Uganda. M.Sc thesis, Makerere University, Uganda

Mwavu, E.N. & E.T.F. Witkowski. 2009a. Seedling regeneration, environment and management in a semi-deciduous African tropical rain forest. Journal of Vegetation Science 20: 791-804

Mwavu, E.N.. & E.T.F. Witkowski. 2009b. Population structure and regeneration of multiple-use tree species in a semi-deciduous African tropical rainforest: Implications for primate conservation. Forest and Management 258 :840-849

Myers, N. 1988. Tropical forests: much more than stocks of wood. *Journal of Tropical Ecology* 4:209-211.

Nabe-Nielsen, J., J. Kollmann, & M. Pena-Claros. 2009. Effects of liana load, tree diameter and distances between conspecifics on seed production in tropical timber trees. Forest Ecology and Management 257: 987-993

Reproductive status of the two timber species *Cariniana ianeirensis* and *Terminalia oblonga* were negatively correlated with liana cover and positively with tree diameter. Suggests that liana cutting on remaining seed trees would improve fertility, and conversely that logging the largest, least infested trees could decrease species regeneration. Bolivia.

Nabe-Nielsen, J., W. Severiche, T. Fredericksen, & L.I. Nabe-Nielsen. 2007. Timber tree regeneration along abandoned logging roads in a tropical Bolivian forest. New Forests 34: 31-40

Suggests intensifying logging in some areas to improve regeneration of light demanding species.

Nair, C.T.S. 1991. A comparative account of silviculture in the tropical wet evergreen forests of Kerala, Andaman Islands and Assam. Pp 371-382 in Gómez-Pompa, A., T.C. Whitmore & M. Hadley (eds.) Rain forest regeneration and management, Paris: UNESCO.

Namkoong,G, T. Boyle, H. Gregorius, H. Joly, O. Savolainen, W. Ratnam & A. Young . 1996. Testing Criteria and Indicators for Assessing the Sustainability of Forest Management: Genetic Criteria and Indicators. CIFOR Working Paper No. 10 Aug. 1996.

Nasi, R. 2005. Potential methodological flaw in the examination of the effects of logging. Ecology and Society 10

Ndoye, O. & J.C. Tieguhong. 2004. Forest resources and rural livelihoods: The conflict between timber and non-timber forest products in the Congo Basin. Scandinavian Journal of Forest Research 19: 36-44

Neil, P. E. 1984. Climber problems in Solomon Islands forestry. Commonwealth Forestry Review 63: 27-34.

Plantations in Solomon Islands, where almost all the canopy is removed, then swamped by Convolvulaceous climbers (*Merremia, Operculina*).

Newbery, D. M. & J. S. Gartlan. 1996. A structural analysis of rain forest at Korup and Douala-Edea, Cameroon. Proceedings of the Royal Society of Edinburgh. 103b: 177-224.

Diameter frequency distributions are classified into 5 types, for 197 tree species >= 30cm gbh; 135 + 104 plots along 8 transects. No evidence for Aubreville's mosaic theory found: small trees grew together with large. *Lophira alata* was regenerating, in spite of Letouzey's comment that it often does not in the same area as adults.

Newbery D. M. , N. C. Songwe, & C. B. Chuyong. 1997. Phenology and dynamics of an African rainforest at Korup, Cameroon. In Dynamics of tropical communities Pp. 267-308 Newbery, D. M. , H. H. T. Prins & N. D. Brown (eds.). 1997. Dynamics of tropical communities. The 37th symposium of the British Ecological society, Cambridge University, 1996. Blackwells Science Ltd

Newbery, D. M. , H. H. T. Prins & N. D. Brown (eds.). 1997. Dynamics of tropical communities. The 37th symposium of the British Ecological society, Cambridge University, 1996. Blackwell Science Ltd. 635 pp.

Newbery, D. M. , N. C. Songwe & G. B. Chuyong, 1998. Phenology and dynamics of an African rainforest at Korup, Cameroon. Pp. 267-308 in Newbery, D. M. , H. H. T. Prins & N. D. Brown (eds.). Dynamics of tropical communities. The 37th symposium of the British Ecological society, Cambridge University

Nichols, J. D. , V. K. Agyeman, F. B. Agurgo, M. R. Wagner & J. R. Cobbinah. 1999. Patterns of seed survival in the tropical African tree *Milicia excelsa*. Journal of Tropical Ecology 15: 451-461.

Observations in Dry Semideciduous forest in Ghana showed surprisingly little infestation of seedlings by *Phytolyma* galls in an area with infested adults. The results did not support the Janzen-Connell hypothesis of distance-dependent mortality, but rather these data and other observations suggest that density dependent mortality (due to the gall) may be important, as well as the fact that the seedlings do not survive in low light levels.

Newstrom, L. E. , G. W. Frankie & H. G. Baker. 1994. A new classification for plant phenology based on flowering patterns in tropical rainforest trees at La Selva, Costa Rica. Biotropica 26: 141-159

Ng, K.K.S., S.L. Lee, & S. Ueno. 2009. Impact of selective logging on genetic diversity of two tropical tree species with contrasting breeding systems using direct comparison and simulation

methods. Forest Ecology and Management 257: 107-116

Pasoh forest plot, Malaysia. Adjacent plot logged by the MUS c.52 years ago was compared with the natural stand of the 50ha plot. Simulation studies were also run to examine the effect of removing individuals of *Shorea leprosula* and *Shorea ovalis* ssp. *sericea* on genetic diversity. Direct comparison of adjacent natural and logged-over stands showed reduction of genetic diversity of *S. leprosula*, but not of. Outcrossing species (*S. leprosula)* might suffer greater loss of genetic diversity after logging than apomictic species (S. *ovalis ssp. sericea*). Simulations of 'logging' in a clump showed much more serious loss of genetic diversity than if individuals were removed at random.

Ng, F. D. P. Strategies of establishment in Malayan forest trees. Pp 129-162 in Tomlinson, P. B. & M. H. Zimmermann (eds.)

Nicholson, D. I. 1958a. Natural regeneration of logged tropical rain forest, North Borneo. The Malayan Forester 21:65-71.

Nicholson, D. I. 1958b. An analysis of logging damage in tropical rain forest, North Borneo. The Malayan Forester 21: 235-245.

Nicholson, D. I. 1963. Damage from high-lead logging in Sabah. Malaysian Forester 26: 294-296.

Nicholson, D. I. 1979. The effects of logging and treatment of the mixed diptercarp forests of south east Asia. FAO: FO/MISC/79/8. FAO, Rome.

This report, in OFI library, is annotated 'March 1979 draft'. The silvics of dipterocarps are reviewed. They mostly correspond to Ghanaian Non Pioneer Light Demanders (Hawthorne, 1996). However, it is claimed that dipterocarps respond generally positively to forest treatments than is the case for African timber trees (citing a conference paper precursor to Dawkins 1959). Includes many tables showing, e. g. amount of damage by size class, under various conditions.

Nicholson, D. I. , N. B. Henry & J. Rudder. 1988a. Stand changes in north Queensland rain forests. Proceedings Ecological Society of Australia 15: 61-80.

Nicholson, D. I., N.B. Henry, & J. Rudder. 1988b. Reply: disturbance regimes in north Queensland rainforests, a re-evaluation of their relationship to species richness and diversity. Australian Journal of Ecology 15: 245-246.

Nicotra, A. B., R. L. Chazdon & S. Iriarte. 1999. Spatial heterogeneity of light and woody seedling regeneration in tropical wet forests. Ecology 80: 1908–1926

Niemela, J.1997. Invertebrates and Boreal Forest Management. Conservation Biology 11: 601-61

Niklas, K. L, 1995. Size dependent allometry of tree height, diameter and trunk taper. Annals of Botany 75: 217-227.

Nolan, T. M. , & K. K. F. Ghartey. 1992. Management of the tropical high forest of Ghana. Pp. 225-234 in Miller, F.R & K.L. Adam (eds.) Wise Management of Tropical Forests. Proceedings of the Oxford conference on tropical forests 1992. Oxford Forestry Institute, University of Oxford. UK.

Outline summary of the historical development and current practices

Novotny, V. 2010. Rain Forest Conservation in a Tribal World: Why Forest Dwellers Prefer Loggers to Conservationists. Biotropica 42: 546-549

Nummelin, M. 1998. Log-normal distribution of species abundances is not a universal indicator of rain forest disturbance. Journal of Applied Ecology 35: 454-457

Nummelin, M. 1989. Seasonality and effects of forestry practices on forest floor arthropods in the Kibale Forest, Uganda. Fauna Norvegica Series B 36: 17-25.

Nummelin, M. 1990. Relative habitat use of duikers, bush pigs and elephants in virgin and selectively logged areas of the Kibale Forest, Uganda. Tropical Zoology 3: 111-120.

Nummelin, M. & L. Borowiec. 1991. Cassidinae beetles of the Kibale Forest, western Uganda: comparison beetles between virgin and managed forest. African Journal of Ecology 29: 10-17.

Nummelin, M. & I. Hanski. 1989. Dung beetles of the Kibale Forest, Uganda: comparison between virgin and managed forest. Journal of Tropical Ecology 5: 349- 352.

Nummelin, M. & S. Kaitala, 2004. Do species dominance indices indicate rain forest disturbance by logging? Biotropica 36: 628-632

Nummelin, M. & J.E. Zilihona. 2004. Spatial variation of arthropod communities in virgin and managed sites in the Kibale Forest, western Uganda. Forest Ecology and Management 195: 107-114

Nunez-Farfan, J. & R. Dirzo. 1988. Within gap spatial heterogeneity and seedling performance in a Mexican tropical forest. Oikos 51: 274-284.

Nussbaum, R. , J. Anderson & T. Spencer. 1995. Factors limiting the growth of indigenous tree seedlings planted on degraded rainforest soils in Sabah, Malaysia. Forest Ecology and management 74: 149-159.

Logging removes topsoil from landings and skid trails, and the subsoil is compacted, nutrient-poor, low in organic matter, drought-prone and hot, hence vegetation recovers slowly. Planted trees (2 *Macaranga* pioneers, two dipterocarps) grow poorly. Fertiliser improved height growth and basal area 6 months after planting; digging had a slight effect; mulching had little effect, suggesting nutrient deficiency is the main problem. Topsoil replacement was as good as fertilisation.

Nuys, G. J. & R. G. Wijers. 1991. Wood waste and logging damage in Nkrabia forest reserve, Ghana. ITTO project PD 74/90: better utilisation of tropical timber resources in order to improce sustainability and reduce negative ecological. M.Sc thesis. Dept. of Forestry, Wageningen Agric. Univ.

Nye, P. M. And Greenland, D. J. 1960. The soil under shifting cultivation. Commonwealth agricultural bureau, England 25-46.

Nykvist, N. 2000. Tropical forests can suffer from a serious deficiency of calcium after logging. Ambio 29:310-313

The harvesting of stem wood and stem bark from a tropical rainforest in Sabah, Malaysia, resulted in the loss of almost 19% of the total calcium in the ecosystem, to 50-cm soil depth

Oates, J.F. 1996. Habitat alteration, hunting and the conservation of folivorous primates in African forests. Australian Journal of Ecology 21: 1-9

Oberbauer, D. F. , D. B. Clarke, D. A. Clarke & M. Quesada. 1988. Crown light environments of saplings of two species of rain forest emergent trees. Oecologia 75: 207-212.

O’Brien, S. T. , S. P. Hubbell, P. Spiro, R. Condit & R. B. Foster. 1995. Diameter, height, crown and age size relationships in eight neotropical tree species. Ecology 76: 1927-1939

O’Brien, S. T. , S. P. Hubbell, R. Condit , S. Loo de Lao & R. B. Foster. 1997. Diameter, height, crown size and trunk diameter of 56 tree and shrub species in a neotropical forest. Functional Ecology 76: 1926-1939

Obua, J. 1992. Frugivore abundance along a logging gradient in the Kibale Forest, western Uganda. Proceedings VIII Pan African Congress Pp 327-333.

Ochoa G., J. 1988. Inventario de los mamiferos de la florestal de Ticoporo y la Serrania de los Pijiguaos, Venezuela. Acta Cientifica Venezolana 39: 269-280.

Offermans, D. M. J. 1986. Crown shyness: a parameter for ageing in *Piptadeniastrum africanum*. Netherlands Journal of Agricultural Science. 4: 493-497.

Ofosu-Asiedu, A. , J. Ofori, & A. R. Adam. 1993. Logging residue generation and forest disturbance and assessment of product yield and wood residues in wood processing mills in Ghana. Report submitted to the International Tropical Timber Organization (ITTO). 201 pp.

Ofosu-Asiedu, A. , A. Oteng-Amoako, V. K. Agyeman, A. R. Adam & E. G. Foli. 1997. Report on felling limit Study. Report submitted to Forestry Department, Accra. 37 pp.

Report on a desk study, including literature and FD inventory data, and a survey in 18 sawmills on the defects in 118 logs from 22 species. PCA was used to define groups with similar stem diameter distributions, growth, mortality and wood quality. The groups so defined have doubtful meaning, especially as the groups were assumed to have the same increments, based on only the few species (12 in totals, based on Alder's earlier PSP study) in each group for which good increment data were known. The stand tables erroneously under-estimate the numbers of trees <20cm dbh because the inventory data was not adjusted for the smaller sample sizes for smaller trees. Hence the attempt to define felling limit groups based on the optimum MAI of the group as a whole is highly suspect. . It is proposed that *Triplochiton* and *Pterygota* have their felling limits reduced due to high incidence of defects for logs supposedly from trees>90cm DBH. The impacts of changing limits were estimated but this is also apparently calculated in error, applying the Interim Yield formula to the average stocking of forest zones as a whole, rather than at the compartment scale

Ogbe, G. A. E. 1956. Notes on *Triplochiton* regeneration and canopy opening in Ilaro forest reserve. Nigerian Forestry Information Bulletin 33.

O'Heix, B.C., J.L. Doucet, R. Ondo, & D. Ingueza. 2002. Criteria and indicators: Initiatives in Gabon. Bois et Forets des Tropiques 271:79-88

Okali, D. U. U. 1972. Growth rates of some West African forest-tree seedlings in shade. Annals of Botany 36: 953-959.

Okali, D. U. U. & B. A. Ola-Adams. 1987. Tree population changes in treated rain forest at Omo Forest Reserve, south-western Nigeria. Journal of Tropical Ecology 33: 291-313.

Oke, S.O. & P.F. Oyedare. 2006. Effects of logging activities on the flora and structure of the vegetation in Isokan area of Southwestern Nigeria. Botanica Lithuanica 12:85-95

Logging activities have resulted in the loss of important timber tree species in the study forest.

Okuda, T. , N. Kachi, S. K. Yap & N. Manokaran. 1995. Spatial pattern of adult trees and seedling survivorship in *Pentaspadon motleyi* in a lowland rain forest in peninsular Malaysia. Journal of Tropical Forest Science 7: 475-489.

No sapling 1-2.5cm dbh found within 6m of adults >40cm dbh, but some under trees of other species.

Okuda, T. , N. Kachi, S. K. Yap & N. Manokaran. 1997. Tree distribution pattern and fate of juveniles in a lowland tropical rain forest – implications for regeneration and maintenance of species diversity. Plant Ecology 131: 155-171

Pasoh, Malaysia. Examination of density-dependent recruitment and mortality; variation of sapling density with distance from adult; General relationship between distributions of samplings and trees; sapling mortality and recruitment between two censuses. 444 spp. 56/444 lower density near adults (29% of emergent spp. are like this), 28 in other layers (11%); 53/444 decline with distance. No support for Janzen hypothesis that juveniles not found near parents, nor that adults more regularly dispersed than juveniles. Emergent and canopy species suffer higher mortality than others

Ola-Adams, B. A. 1987. Effects of logging on the residual stands of a lowland forest at Omo Forest Reserve, Nigeria. The Malaysian Forester 50: 403-413.

Results based on a single 1ha plot located subjectively in a five month old logged compt. Logging was 'manual' with trees cross cut and loaded directly onto lorries which gained access along hand-cut access routes. Undisturbed forest there generally has a Basal Area of c. 29 m^2 /ha; disturbed forest has 14. 3 m^2/ha and secondary regrowth 11.7 m^2 /ha. The commonest trees in the plot were *Sterculia rhinopetala, Strombosia* and *Diospyros* spp. ('Moist evergreen'). Trees>10cm gbh (girth) were measured and tracks mapped. c. 9m^3/ha were extracted in the forest as a whole. The 1 ha. plot had 3 stumps; with 670 trees left>10cm gbh. 17.74% had suffered some form of damage (crown= 9.4%; branch = 1.19%; stem=0.09%; remainder= unknown). 51 trees had been knocked over, mostly in the '+30cm girth class' mostly along tracks and around harvested trees. The maps showed damage left 8% of the ground bare (compared with 30% for mechanised logging).

Oldeman, R .A. A., 1983 Tropical rainforest, architecture, silvigenesis and diversity. Pp 139-150. in S.L Sutton, T.C Whitmore & A.C. Chadwick,In: Tropical rainforests: ecology and management. (eds .) British Ecological Society Special publication 2.

Oldeman, R. A. A. & J. van Dijk. 1991. Diagnosis of the temperament of tropical forest trees. Pp 21-65 in Gomez-Pompa *et al.* (eds.).

Discussion of tree architecture and temperament, including aberrations from Horn (1971) such as large-leaved nearly mono-layer, light-demanding trees like *Musanga* (see also Givnish, 1984); and pauci-layer 'pagoda-trees' of *Terminalia* and *Alstonia.* Suppressed juveniles of canopy trees have tall narrow crowns. Gymnosperms and palms are also discussed.

Oldfield, S. 1990. Paper given at ITTO/IIED seminar on the conservation impact of the increased harvesting of lesser known species held in London, 4 - 5.

Olupot, W. 2000. Mass differences among male mangabey monkeys inhabiting logged and unlogged forest compartments. Conservation Biology 14: 833-843

Olupot, W., C.A. Chapman, C.H Brown, & P.M. Waser. 1994. Mangabey (*Cercopithecus albigena*) population density, group size and ranging: a twenty-year comparison. American Journal of Primatology, 32: 197- 205

Oni, O. , F. E. Fasehun & D. O. Ladipo. 1991. Flowering in the West African hardwood *Terminalia ivorensis* A. Chev. Nigerian Journal of Forestry 1-2: 42-46.

Onojeghuo, AO; Blackburn, GA. 2011. Forest transition in an ecologically important region: Patterns and causes for landscape dynamics in the Niger Delta. Ecological Indicators 11: 1437-1446

Opler, P. A. , G. W. Frankie & H. G. Baker. 1980. Comparative phenological studies of treelet and shrub species in tropical wet and dry forests in the lowlands of Costa Rica. *Journal of Ecology* 68: 167-188.

Orgle, T.K. 1994. Ecology of burnt forests in Ghana. Ph.D. Thesis, University of Aberdeen.

Osafo, E. D. 1958. A study of the variation and size-class distribution in some forest reserves in Ghana.

Osafo, E.D. 1970. The development of silvicultural techniques applied to natural forests in Ghana. FPRI Technical Note. No. 13.

Otieno, N.E., M. Muchane, & S. Karimi. 2007. Effect of logging on the Abbott's Starling (*Pholia femoralis*) population in Kikuyu escarpment forest, Kenya. Ostrich 78: 299-304

Owiunji, I. 2000 Changes in avian communities in Bundongo Forest Reserve after 70 years of selective logging. Ostrich 71: 216-219

Owiunji, I. & A.J. Plumptre, 1998. Bird communities in logged and unlogged compartments in Budongo Forest, Uganda Forest Ecology and Management 108:115-126

Palgrave, M.C., A.E. Van Wyk, M. Jordaan, J.A. White, & P.A. Sweet. 2007. Reconnaissance survey of the woody flora and vegetation of the Catapu logging concession, Cheringoma District, Mozambique Biothalia 37: 57-73

Checklist of 238 woody species (trees, shrubs, lianes). Includes the Sena names for 191 species, 77 of which are recorded for the first time.

Pancel, L. 1993. Tropical Forestry handbook (Vols. 1 & 2). Springer-Verlag.

Broad ranging, extensive overview. Makes available various literature otherwise not so easily found. E.g. Chapters 20-21 by Sessions and Heinrich on forest roads and harvesting (pp 1269-1424) reviews many aspects e. g. of ideal spacing of various levels of road- or skidding, including five main skidding patterns (parallel, radial, starburst, random and herring-bone). Ghana's preferred method could add another -'dendritic', a hybrid of herringbone and random. Equations are given for optimising road, spur road and skidder distances.

Panfil, S. N. & R. E. Gullison. 1998. Short term impacts of experimental timber harvest intensity on forest structure and composition in the Chimanes Forest, Bolivia. Forest Ecology and Management 102: 235-243.

Harvest manipulated from 1 to 6 trees/ha. Damage increased in a quadratic function of harvesting intensity, with less damage per tree felled at higher intensities due to reuse of skid trails and overlapping of felled tree gaps. The median distance of residual forest to the nearest gap decreased from 25m for 1 tree/ha. to 8.3m at 6 trees/ha. Although mortality increased in proportion to total basal area extracted (quadratic function), residual basal area damage was low because damage was concentrated on small trees. For commercial species, seedlings and saplings of only *Hura crepitans* had a higher significantly increased relative growth rate related to harvest intensity.

Pannell, C. M. 1989. The role of animals in natural regeneration and the management of equatorial rainforests for conservation and timber production. Commonwealth Forestry Review 68: 309-313.

Parren, M. E. 1991. Forest elephant (*Loxodonta africana cyclotis* Matschie) messenger-boy or bulldozer? The possible impact on the vegetation, with special reference to 41 tree species of Ghana. A. V. 90/51. Dept. of Forestry, Wageningen Agric. Univ. , The Netherlands.

Parren, M. P. E. 1991. Silviculture with natural regeneration: A comparison between Ghana, Cote d'Ivoire and Liberia. AV. no. 90/50. Dept. of Forestry, Wageningen Agric. Univ. , The Netherlands.

Overview of forestry in Upper Guinean rain forests. There were some colonial differences. Ghana and Liberia favoured natural regeneration while the French favoured artificial regeneration. In some cases, important silvicultural records were not available. Forest managers often are unaware of the basis on which past decisions have been made. Tropical Shelterwood and similar silviculture proved too complicated and uneconomical due to poor gains in increment. See Parren and de Graaf (95) for updated version.

Parren, M. & F. Bongers. 2001. Does climber cutting reduce felling damage in southern Cameroon? Forest Ecology and Management 141: 175-188

33 square 1-ha research plots were established over an area of 500 ha. In 5 control plots, no logging and no silvicultural treatments were applied. The remaining 28 plots were all logged and in 16 of them pre-exploitation climber cutting was applied. Felling was carried out 9 months later. Harvest levels were set at one tree per ha over 60 cm DRH, resembling normal exploitation practice in the region (but a very low harvest level in general).Lianas were very abundant here compared with other plots globally. Some 70% of monitored lianas had died 22 months after cutting. Felling gapsizes averaged 550m^2 per felled tree, and tree mortality averaged 12 trees per felled tree, with 20 other trees damaged. These figures were not significantly reduced by pre-felling climber cutting. Suggest that only very big lianas are cut on trees to be logged, and only those lianas that are significantly weaker once dead.

Parren, M. P. E. & N. R. de Graaf. 1995. The quest for natural forest management in Ghana, Cote d'Ivoire and Liberia. Tropenbos Series No.13. Blackhuys, Leiden.

A review of forestry in Upper Guinea; somewhat eclectic in places, rather than encyclopaedic, nevertheless reviews many articles, theses etc. in French and English which can be hard to obtain e.g. includes a map of logging damage in Nkrabia from Nuys & Wijers (1991). A useful summary of methods in the three countries listed in title.

Parren, M.P.E. & F. Doumbia. 2005. Logging and lianas in West Africa. Pp 183-201 in Bongers, F., M.P.E. Parren & D. Traore (eds.) Forest Climbing Plants of West Africa: Diversity, Ecology and Management. CABI publishing. 273pp

Parrotta, J. A. Influence of overstory composition on understory colonization by native species in plantations on a degraded tropical site. 1995. Journal of Vegetation Science 6.5: 627-636.

Pattemore, V. & J. Kikkawa. 1974. Comparison of bird populations in logged and unlogged rain forest in Wiangarie State Forest, N.S.W. Australian Forester 37: 188-198.

Paul, J.R., A.M. Randle, C.A. Chapman, & L.J. Chapman. 2004. Arrested succession in logging gaps: is tree seedling growth and survival limiting? African Journal of Ecology 42: 245-251

Acanthus pubescens gaps have lower densities of natural seedlings than the adjacent forest, and very few small trees emerge from the vegetation within the *A. pubescens* gaps. Elephants come to feed on *A. pubescens*, and contribute to the collapse of these stands, which smothers regenerating natural seedlings and arrests succession. Harvesting *A. pubescens* as a fuel source would be beneficial to local people and would contribute to the establishment of natural tree seedlings.

Payne, J. 1988. Orang-utan conservation in Sabah. Kuala Lumpur: WWF-Malaysia.

Peh, K.S.H., J. de Jong, N.S. Sodhi, S.L.H. Lim, & C.A.M. Yap. 2005. Lowland rainforest avifauna and human disturbance: persistence of primary forest birds in selectively logged forests and mixed-rural habitats of southern Peninsular Malaysia. Biological Conservation 123: 489-505

Pena-Claros, M., T.S. Fredericksen, A. Alarcon, G.M. Blate, U. Choque, C. Leano, J.C. Licona, B. Mostacedo, W. Pariona, Z. Villegas, & F.E. Putz. 2008. Beyond reduced-impact logging: Silvicultural treatments to increase growth rates of tropical trees. Forest Ecology and Management 256: 1458-1467

Pena-Claros, M., E.M. Peters, M.J. Justiniano, F. Bongers, G.M. Blate, T.S. Fredericksen, & F.E. Putz, Regeneration of commercial tree species following silvicultural treatments in a moist tropical forest. Forest Ecology and Management 255: 1283-1293

Peres, C.A., J. Barlow, & W.F. Laurance. 2006. Detecting anthropogenic disturbance in tropical forests. Trends in Ecology & Evolution 21: 227-229

Peres, C.A., M.R. Carmona, J.M. Farina, & J.J. Armesto. 2009. Selective logging of lowland evergreen rainforests in Chiloe Island, Chile: Effects of changing tree species composition on soil nitrogen transformations. Forest Ecology and Management 258: 1660-1668

Perez, M.R., D.E. De Blas, R. Nasi, J.A. Sayer, A. Karsenty, M. Sassen, C. Angoue, N. Gami, O. Ndoye, G. Ngono, J.C. Nguinguiri, D. Nzala, B. Toirambe, & Y. Yalibanda. 2006. Socioeconomic constraints, environmental impacts and drivers of change in the Congo Basin as perceived by logging companies. Environmental Conservation 33: 316-324

Perez-Batallon, P., G. Ouro, F. Macias, & A. Merino. 2001. Initial mineralization of organic matter in a forest plantation soil following different logging residue management techniques. Annals of Forest Science 58:807-818

Perez-Salicrup, D.R., A. Claros, R. Guzman, J.C. Licona, F. Ledezma, M.A. Pinard, & F.E. Putz, 2001. Cost and efficiency of cutting lianas in a lowland liana forest of Bolivia. Biotropica 33:324-329

Peters, S.L. & J.R. Malcolm, B.L. Zimmerman. 2006. Effects of selective logging on bat communities in the southeastern Amazon. Conservation Biology 20: 1410-1421

Peterson, C.J. & A.D. Leach. 2008. Limited salvage logging effects on forest regeneration after moderate-severity windthrow. Ecological Applications 18: 407-420

Moderate-severity natural disturbances followed by moderate-intensity salvaging may have little detrimental effect on forest regeneration and diversity in these systems (west-central Tennessee, USA). No sign of 'threshold changes'.

Petter, J.J. & A. Peyrièras. 1974. A study of population density and home ranges of *Indri indri* in Madagascar. Pp 39-48 in Martin, R.D, G. A. Doyle & A. C. Walker, (eds.) Prosimian Biology, London: Duckworth

Philip, M. S. 1967. The dynamics of seedling populations in a moist semi-deciduous tropical forest in Uganda. I. Interim report on research plot 441, Uganda Forest Department. (Pap. 9th Commonw. For. Conf. , New Delhi 1968).

Philip, M. S. 1983. *Measuring trees and forests.* University Press, Dar-es-Salaam. 338pp.

Phillips, I.D., T.P. Cobb, J.R. Spence, & R.M. Brigham. 2006. Salvage logging, edge effects, and carabid beetles: Connections to conservation and sustainable forest management. Environmental Entomology 35: 950-957

Pinnard, M. , B. Howlett & D. Davidson. 1996. Site conditions limit pioneer tree recruitment after logging of dipterocarp forests in Sabah, Malaysia. Biotropica 28: 2-12.

Logging operations leave denuded vegetation and topsoil vulnerable to erosion. Pioneer species create special conditions. In lightly disturbed areas and on skid trails and landings pioneer species do not increase greatly. To increase the amount of pioneer trees on skids and landings, ground must be first being treated for the compaction that has occurred during logging operations. Seed source is less of a limitation than suitable microsite availability.

Pinard, M.A., M.G. Barker & J. Tay. 2000. Soil disturbance and post logging forest recovery on bulldozer paths in Sabah, Malaysia. Forest Ecology and Management 130: 213-225

RIL-guidelines reduced the extent of roads and skidding trails from 17% to 6%, and those skid trails were less severely disturbed than in conventionally logged areas. Minimizing soil and stand disturbance during logging appears to allow a more rapid recovery of vegetation on bulldozed soils. RIL involved: 1) planning skid-trails in advance of felling; 2) bulldozers restricted to slopes <35o; 3) RIL restricts bulldozer blade use and encourages the use of the winch cable.

Pinard, M.A. & Cropper, W.P. 2000. Simulated effects of logging on carbon storage in dipterocarp forest. Applied Ecology 37: 267-283

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79% of trees > 20cm dbh left after logging carried vines in crowns 13-14 yrs later. On 62% from neighbouring trees, on the others from the ground. Isolated trees with max support diameter were often infested with twining and tendril climbing vines, which climbed up root and branch twiners (succession of vine types).

Pinard, M. A. & F. E. Putz. 1996. Retaining forest biomass by reducing logging damage. Biotropica 28: 278-295.

Estimate of Carbon retained by reducing logging damage (Sabah, Malaysia). 41% trees were damaged by normal methods; 15% by RIL. 44% or 67% of pre-logging biomass retained in normally or RIL-logged forest.

Pinto Henriques, L.H., J.M. Wunderle, D.C. Oren, & M.R. Willig. 2008. Effects of low impact selective logging on an Understory bird community in the Tapajos National Forest, Para, Brazil. Acta Amazonica. 38:267-289

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Plumptre, A.J., 1996. Changes following 60 years of selective timber harvesting in the Budongo Forest Reserve, Uganda. Forest Ecology and Managent 89: 101–113.

Plumptre, A. J. 1995. The importance of “seed trees” for the natural regeneration of selectively logged forest. Commonwealth Forestry Review 74: 253-258.

Budongo forest, Uganda. 5x 2km transects in each of 8 compartments with 7 metre circular plots at 100m intervals, all trees >10cm dbh. Total of 5640 trees visited twice a month from Jan 1993-Jan 1994. Assessed fruits etc on a 0-4 scale (1=1-25% crown with plant part, 4=75 %+). Timber and primate food trees. *Khaya anthotheca, Entandrophragma spp, Holoptelea, Maesopsis, Chrysophyllum albidum, C. perpulchrum, Antiaris, Albizia spp (6), Strychnos mitis, Funtumia elastica, Ficus sur, Cynometra alexandrii, Celtis durandii, C. mildbraedii, C. zenkeri, Aningeria altissima.* Fruit scores estimated as DBH x mean phenology score. From inventory data, estimates of total fruit production in logged and unlogged. % of trees fruiting: 25% maximum at 25-35cm (*Khaya, Maesopsis,Holoptelea Chrysophyllum, Antiaris, Albizia)* or larger (*Entandrophragma*= 70cm*);* fruit production roses to a peak at 100cm (*Entandrophragma),* or 70-90 *(Khaya*) or 50-70 (others). % of trees fruiting reaches 100% at lower sizes (*Funtumia, Aningeria, Celtis* =40 cm). For small trees logged and unlogged similar production, but for *Khaya & Entandrophragma* fruit production less in exploited forest (because fewer large trees). *Khaya* shows highest correlation with seedling density for trees > 50 cm dbh.

Plumptre, A.J. 2006. The diets, preferences, and overlap of the primate community in the Budongo Forest Reserve, Uganda - Effects of logging on primate diets Pp 345-371 in Newton-Fisher, N.E., H. Notman, J.D. Paterson, & V. Reynolds (eds.) Primates of Western Uganda University of Chicago Press. 509pp

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Poorter, L. & M. J. A. Werger. 1999. Light environment, sapling architecture, and leaf display in six rain forest tree species. Americaan Journal of Botany 86: 1464-1473.

Cecropia, Bellucia (Melastome) Tachigalia, Carniana, Theobroma, Capirona from Bolivia. Comparison of architecture and leaf display in relation to shade-tolerance. Species differed in realised height and crown expansion per unit biomass in whole range of forest light conditions, but these differences were not related to shade-tolerance. No evidence for pioneers as multi-layered and shade-tolerant as mono-layered. Sun plants of all spp. had a similar crown area, deeper crown and higher LAI than shade plants.

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Popma, J. , F. Bongers, M. Martinez-Ramos, & E. Veneklaas. 1988. Pioneer species distribution in treefall gaps in neotropical rain forest: a gap definition and its consequences. Journal of Tropical Ecology 4: 77-88.

Popma, J., F. Bongers. & M. J. A . Werger 1992. Gap-dependence and leaf characteristics of trees in a tropical lowland forest in Mexico. Oikos 63: 207-214.

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Poulsen, J.R., C.J. Clark, G. Mavah, & P.W. Elkan. 2009. Bushmeat Supply and Consumption in a Tropical Logging Concession in Northern Congo. Conservation Biology 23: 1597-1608

Development of industrial logging operations led to a 69% increase in the population of logging towns and a 64% increase in bushmeat supply.

Presley, S.J., M.R. Willig, L.N. Saldanha, J.M. Wunderle, & I. Castro-Arellano. 2009. Reduced-impact Logging has Little Effect on Temporal Activity of Frugivorous Bats (Chiroptera) in Lowland Amazonia. Biotropica 41: 369-378

Presley, S.J., M.R. Willig, J.M. Wunderle, & L.N. Saldanha. 2008. Effects of reduced-impact logging and forest physiognomy on bat populations of lowland Amazonian forest. Journal of Applied Ecology 45: 14-25

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Primack, R. B. & P. Hall. 1995. Biodiversity and forest change in Malaysian Borneo. Bioscience 42: 829-837.

Primack, R. B. , P. Hall, & H. S. Lee. 1987. The silviculture of dipterocarp trees in Sarawak, Malaysia IV: Seedling establishment and adult regeneration in a selectivley logged forest and three primary forests. The Malaysian Forester 50: 162-178.

Mixed dipterocarp forest in Sarawak, selectively logged in 1973/4. Given three different intensities of liberation thinning and removal of relics to increase the growth rate. Amount of seedlings appeared to be enough to replenish dipterocarps. For Red Meranti there were much lower ratios of seedlings and saplings to adult trees than in the primary forest (in logged=1.9 to 4.5 times as many saplings as adults; 5.6 to 19.4 times as many seedlings as adults) & suggest that logging has a detrimental effect.

Pringle, C. M. & J.P. Benstead. 2001. The effects of logging on tropical river ecosystems. Pp 305-325 in Fimbel, R.A., A. Grajal and J.G Robinson (eds.) The cutting edge: conserving wildlife in logged tropical forest. Columbia University Press New York USA

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Proctor, J. 1992. Soils and mineral nutrients: what do we know, and what do we need to know for wise rain forest management. Pp. 27-35 FR Miller, F.R. & K.L.Adam, Wise Management of Tropical Forests. Proceedings of the Oxford conference on tropical forests 1992. Oxford Forestry Institute, University of Oxford. UK.

Experimental studies yield conflicting results, and classification schemes and maps are inadequate. However, soil nutrients are only of crucial importance where severe disturbances (e. g. conversion) occur.

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Putz, F. E. 1984. The natural history of lianas on Barro Colorado island, Panama. Ecology 65: 1713-1724.

Liana abundance, height, diameter and climbing mode studied on Barro Colorado, Panama. Sample plots were 100m^2 cylinders from ground up, located randomly in 3 different stages of recovery from treefall. 1597 climbing lianas/ha were in 43% of the trees in old growth. Trellis availability was a major factor limiting liana access to forest canopy. Edges of gaps, with many small stems, are a major pathway to the canopy. Few lianas die with host tree. Tree sapling growth rates were lower where lianas abundant.

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Putz, F.E., D.P. Dykstra, & R. Heinrich. 2000. Why poor logging practices persist in the tropics. Conservation Biology 14:951-956

Putz, F. E. , H. S. Lee & R. Goh. 1984. The effects of post-felling silvicultural treatments on woody vines in Sarawak. The Malaysian Forester 47: 214-226.

Study of how vines affect tree regeneration, and how treatment affects vines. The effects on % trees carrying vines are compared of several post-felling silvicultural treatments (tree thinning and vine-cutting). Form and growth rates of trees are studied 3-5 yrs after treatment. Treatments were liberation thinning (girdle trees competing with potential timber) and several variants of the generally more severe Malayan Uniform System (trees surviving logging are poison girdled). In all treatments all woody vines had been cut.

Pioneer trees in all plots carried vines significantly less frequently than 'preferred' and 'acceptable' timber species. Pioneer trees were more common in treated plots, so this obscured the relationship between treatment and vine abundance. In some MUS plots, vines were more common than in untreated plots in spite of removal of vines from the former five years earlier. The worst vine tangles were in abandoned log yards and along old roads, where pioneers also abound, so the dissociation is more remarkable. Hypotheses to account for the effect include: fast 'escape' growth of the trees; Greater 'swaying' or more flexible pioneers (discounted); greater shedding of large pioneer leaves (discounted); ants, as most the pioneers were Macaranga. The pioneers may be acting as a protective 'cover crop' for timber trees.

Vines had a slight negative effect on tree growth rates; the effect was expected to rise with time. Some trees were completely smothered, but most had a few small vines. However infestation was only recorded as presence/ absence, so potential effects on growth were probably underestimated. Nearly 50% of vine stems were of sprouts from vines which fell during logging. Post felling vine cutting was not very effective, and pre-felling vine-cutting is recommended.

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Putz, F. E. & M. A. Pinard. 1995. The reduced-impact logging project in Sabah, Malaysia. Abstract: Proc. 10 IUFRO world congress. Abstract.

1400 ha. logged under best management practice (BMP) are compared to a similar area logged conventionally. RIL guidelines stipulate vine-cutting, 100% stock mapping, directional felling, marking potential crop trees likely to be damaged during skidding and felling, and much planning and supervision. RIL resulted in 50% reduction in severe damage to residual tees and soil relative to conventional. Problems arose with bad weather, and using bulldozers on steep terrain.

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Putz, F.E., L.K. Sirot & M.A. Pinard. 2001. Tropical forest management and wildlife. Silvicultural: effects on forest structure, fruit production, and locomotion on arboreal animals Pp 11-34 in Fimbel, R.A., A. Grajal & J.G Robinson (eds.) The cutting edge: conserving wildlife in logged tropical forest. Columbia University Press New York USA

Putz, F.E., P. Sist, T. Fredericksen, & D. Dykstra. 2008. Reduced-impact logging: Challenges and opportunities. Forest Ecology and Management 256: 1427-1433

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“We tested: (1) the speed at which lianas recruit into logging gaps and their dynamics afterwards; and (2) whether pre-harvest liana cutting actually reduces the abundance of lianas in post-harvest logging gaps. To test hypothesis 1, we compared liana recruitment in new, 1 and 6-year-old logging gaps. For hypothesis 2, we compared liana abundance and tree infestation by lianas in 1-year-old logging gaps in which all lianas had been cut 9 months prior to tree felling vs. 1-year old logging gaps in which lianas were not cut. Lianas recruited heavily into logging gaps within 1 year, mostly by means of stem sprouts, and many of these new stems were apparently able to persist for longer than 6 years. Lianas were significantly more abundant in the root/bole zone of gaps than in the canopy zone, mostly due to the vigorous regeneration of stem sprouts. Canopy openness was highest in gaps one year after logging, possibly due to the smothering effect of the lianas on developing trees. Although liana abundance increased significantly over the 6-year gap chronosequence, direct liana infestation of trees remained the same. Pre-logging liana cutting, however, significantly reduced the number of lianas and also the number of liana-infested trees in logging gaps. Consequently, liana cutting appears to be an effective method to reduce the abundance of lianas and thus minimize their detrimental effects on regenerating trees in logging gaps.”

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Sheil, D. & D. Burslem. 2003. Disturbing hypotheses in tropical forest. Trends in Ecology & Evolution 18: 18-26

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Silva, J. M. N. , J. O. P. de Carvalho, J. de C. A. Lopes, B. F. de Almeida, D. H. M. Costa, L. C. de Oliveira, J. K. Vanclay & J. P. Skovsgaard. 1995. Growth and yield of a tropical rain forest in the Brazilian Amazon 13 years aftr logging. Forest Ecology and management 71: 267-274.

36 PSPs in Tapajos forest, Brazil established in 1981 in forest logged in 1979. They were remeasured in 1987 and 1992. Logging reduced shade-tolerants and stimulated light-demanders. Over 11 years stem number and BA increased, and the final stand had 75% basal area of adjacent unlogged forest. Growth stimulated by logging lasted only three years, and in last survey was similar to normal.

Silva, J. N. M. , J. O. P de Carvalho, J. de C. A. Lopes, R. P. De Oliveira, & L. C. de Oliveira. 1996. Growth and yield studies in the Tapajos region, central Brazilian Amazon. Commonwealth Forestry Review 75: 325-329.

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Sist, P., D. Sheil, K. Kartawinata & H. Priyadi 2003 Reduced impact logging in Indonesian Borneo: some results confirming the need for new silvicultural prescriptions. Forest ecology and Management 179:415-427

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Struhsaker, T. T., J. S. Lwanda & J. M. Kasenene. 1996. Elephants, selective logging and forest regeneration in the Kibale forest, Uganda. Journal of Tropical Ecology 12: 45-64.

Elephants used heavily logged (large gaps) more than lightly logged or unlogged (small or no gaps) areas. Higher % damage by elephants to small trees in heavily logged forest. Elephant use related to density of herbaceous tangle. They perpetuate gaps by damaging young trees. The tangles compete with young trees, attract rodents and elephants and facilitate windthrow. Reduce logging and incidental damage used to prevent elephant damage.

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Useful summary of forest dynamics, with bias towards Ghana, including some data not published elsewhere, e.g. distribution profile of seeds around a *Khaya ivorensis* tree; and phenology diagrams for trees in Bia South GPR, Ghana.

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Swaine, M. D. , W. D. Hawthorne & T. K. Orgle. 1992. The influence of fire on savanna vegetation at Kpong, Ghana. Biotropica 24: 166-172.

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Synnott, T. J. 1979. A manual of permanent plot procedures for tropical rainforests. Tropical Forestry Papers. No. 14. Department of Forestry. Commonwealth Forestry Institute, Oxford. 67pp.

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Tachie-Obeng, E. 1994. Nutrient content in some Logs of Tropical Timber Trees in Ghana. (A case study in Bura Forest Reserve). B. Sc. Thesis IRNR. UST. Kumasi 70 pp.

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Including some details of mortality following logging. Trengannu and other hill forest in Malaysia: 20-30 cm dbh trees dbh grew fastest in Trengganu, but Selangor 60cm dbh fastest; basal area loss in first few years after logging due to mortality. Mean mortality of trees one year after logging strongly correlated with logging intensity (2. 8% to 10. 2%) mainly due to damage to individual trees. Undamaged trees in low intensity logging had 1.3% mortality. 16 or 18 plots showed a decline in growth rates after logging; selection cutting not advisable due to high logging damage, soil erosion, probability of advanced regrowth not responding to canopy opening; hence need more intensive management of ridges and valleys.

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A silvicultural manual for timber trees in Ghana, covering basic ecology and distribution; seed weights, germination and nursery techniques; identification notes etc.

Taylor,C. J. 1947. Yield marking in mixed tropical forest. Empire Forestry Review 26.

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Taylor, D. M. , A. C. Hamilton, J. D. Whyatt, P. Mucunguzi & R. Bukenya-Ziraba. 1996. Stand dynamics in Mpanga research forest reserve, Uganda, 1968-1993. Journal of Tropical Ecology 12: 583-597.

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Ter Steege, H. 1996. Ecology and logging in a tropical rain forest in Guyana, with recommendations for forest management. Tropenbos Series. Blackhuys, Leiden.

Overview of products of the Tropenbos in Guyana, with emphasis on management prescriptions. Pages 39-59 deals with the effects of logging, on soil, microclimate, nutrients, plant and animal ecology. Adoption of the principles of the CELOS system from Suriname are recommended (Hendrison, 1990), mostly corresponding to Reduced Impact Logging (RIL); IITO's (1990) guidelines are also promoted.

Terborgh, J, N. C. Flores, P. Mueller & L. Davenport. 1997. Estimating the ages of successional stands of tropical trees from growth increments. Journal of Tropical Ecology14: 833-856.

Even-aged stands along Amazonian river meanders. Method generates best estimate lifetime growth trajectories, found to give estimated within 5 to 20% of known stand ages.

Thiollay, J.M. 1992. Influence of selective logging on bird species diversity in a Guianan rain forest. Conservation Biology 6: 47-63.

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Thomas, S. C. 1996a Relative size at onset of maturity in rain forest trees: a comparative analysis of 37 Malaysian species. *Oikos* 76: 145-154

Thomas, S. C. 1996b Asymptotic height as a predictor of growth and allometric characteristics in Malaysian rain forest trees. *American Journal of Botany* 83: 556-566

Thomas, S. C. & S. Appanah. 1995. On the statistical analysis of reproductive size thresholds in dipterocarp forests. Journal of Tropical Forest Science 7: 412-418.

Smaller trees appear to be fruiting in logged dipterocarp forest (Appanah & Manaf, 1990), but the mean size of fruiting trees in logged forest may be depressed due to loss of larger trees, hence suggested to estimate a threshold size rather than mean. This is not significantly, but apparently lower in logged forest.

Thomas, S. C. & F. A. Bazzaz. 1999. Asymptotic height as a predictor of phosynthetic characteristics in Malaysian rain forest trees. Ecology 80: 1607-1622.

28 late-successional species from Pasoh, Malaysia, from understory treelets to canopy trees in four genera (*Garcinia, Baccaurea, Diospyros, Aporusa*). Light-saturated photosynthetic rate (Amax) of understory saplings positively correlated with asymptotic height. Time of peak occurrence following land clearance explained 90% of variance in Amax, whereas cruder successional indicators explained only 31% (citing *Reich et al.* , 1995)

Thompson, JR; Spies, TA. 2010. Factors associated with crown damage following recurring mixed-severity wildfires and post-fire management in southwestern Oregon. Landscape Ecology 25: 775-789

Tinal, U. & J. L. Palenewen. 1978. Mechanical logging damage after selective logging in the lowland dipterocarp forest at Baloro, East Kalimantan. BIOTROP special publication. 91-96.

Tilman, D. 1999. Diversity by default. Science 283: 495-496.

Response to Hubbell *et al.* (1999).

Toledo, M; Poorter, L; Pena-Claros, M; Alarcon, A; Balcazar, J; Leano, C; Licona, JC; Llanque, O; Vroomans, V; Zuidema, P; Bongers, F. 2011. Climate is a stronger driver of tree and forest growth rates than soil and disturbance. Journal of Ecology 99: 254-264

Tomlinson, P. B. & M. H. Zimmermann (eds.). 1978. Tropical trees as living systems. Cambridge

University Press. Cambridge.

Tomlinson, P. B. 1978. Branching and axis differentiation in tropical trees. Pp 187-208 in Tomlinson, P. B. & M. H. Zimmermann (eds.)

Tomlinson, P. B. 1987. Architecture of tropical plants. Annual Review of Ecology and Systematiics 18:1-21

Toriola D., P. Chareyre & A. Buttler. 1998. Distribution of primary forest plant species in a 19-year old secondary forest in French Guiana. Journal of Tropical Ecology 14: 323–340.

Torquebiau, E.F. 1986 Mosaic Pattern in dipterocarp rainforest in Indonesia, and their implications for practical forestry. Journal of Tropical Ecology. 2: 301-325

Trockenbrodt, M. Z Imiyabir and J. Josue 2002. Hollow logs and logging residues from Deramakot Forest Reserve Sabah Malaysia. Forest Ecology and Management 165:141-150

Tufuor, K. & P. B. Sharp. 1978. Flowering and fruiting patterns in important Ghanaian timber trees. *Terminalia ivorensis* (A. Chev.) and *Terminalia superba* (Engl. & Diels). Technical Note. Forest Products Research Institute, Ghana. i + 10pp.

Turner, I. M. 1990. Tree seedling growth and survival in a Malaysian rain forest. Biotropica 22: 146-154. Malaysian seedling mortality ten times higher, when reach 10-20cm in height than when 30-40cm high.

Turner, I. M., H. T. W. Tan & K. S. Chua. 1996. Relationships between herb layer and canopy composition in a tropical rainforest mosaic in Singapore. Journal of Tropical Ecology 12: 843–851.

DCA ordination of the herb flora gave a similar result to that for their canopy composition for 0.2ha plots in Singapore PSP.

Turner I. M., Y. K. Wong, P. T. Chew & A. bin Ibrahim. 1997. Tree species richness in primary and old secondary tropical forest in Singapore. Biodiversity and Conservation 6: 537–543.

Mean species number per plot in the more diverse of the two secondary forests (ex agriculture) was only about 60% of the primary forest despite a century or so for colonization by species and the presence of contiguous primary forest.

Tutin, C.E.G. & M. Fernandez, 1993. Relationships between minimum temperature and fruit production in some tropical forest trees in Gabon. Journal of Tropical Ecology 9: 241-248.

Tutin, C.E.G. 2000. Ecology and social organisation of African rainforest primates: relevance for understanding the transmission of retroviruses. Bulletin de la Societe de Patholgie Exotique 93: 157-161

Tutin, C. E. G. & L. J. T. White 1997. Primates, phenology and frugivory: present, past and future patterns in the Lope reserve, Gabon. Pp. 309-337 in Newbery *et al.*

Tweheyo, M. & K.A. Lye. 2005. Patterns of frugivory of the Budongo forest chimpanzees, Uganda. African Journal of Ecology 43: 282-290

Uhl, C. 1982. Recovery following disturbances of different intensities in the Amazon rain forest of Venezuela. Interciencia 7:19-24.

Uhl, C. & R. Buschbacker. 1985. A disturbing synergism between cattle ranch burning practices and selective tree harvesting in the eastern Amazon. Biotropica 17: 265-268.

Uhl, C. & I. C. G. Vieira. 1989. Ecological impacts of selective logging on the Brazilian Amazon, a case study from the Paragominas region of the state of Para. Biotropica 21: 98-106.

Vast increase in interfluvial logging recently: much of it in Para. This study based on logging roads; plots (total area 6.8 ha) extended 50m into forest, wherein all trees >10cm dbh were mapped and measured. 52 m^3 /ha extracted. 53 trees (8/ha.) were harvested=1.7% of all trees

>10cm dbh. 12% >10 cm dbh lost crowns; also 11% uprooted; 3% suffered bark damage. Hence 2% harvested, but 26% killed or damaged. 16% BA was extracted, but an extra 28% BA damaged. Canopy cover c. halved from 80%. 8% of total logged areas were roads, of which primary roads were half (18% of road length).

Uhl, C. , C. Jordan, K. Clark, H. Clark & R. Herrera. 1982. Ecosystem recovery in Amazon caatinga forest after cutting, cutting and burning, and bulldozer clearing treatments. Oikos 38: 313-320.

Ecosystem recovery evaluated by measuring vegetation composition, biomass, nutrient accumulation, soil characteristics and nutrient leaching. Increased disturbance changed early successional vegetation. 100 yr required for the cut and cut-and-burnt patches to recover. Bulldozed vegetation > 100 yr to recover.

Uhl, C. , K. Clark, N. Dezzeo, P. Maquirino. 1988. Vegetation dynamics in Amazonian treefall gaps. Ecology 69: 751-763.

Uhl, C. , A. Verissimo, M. M. Mattirs, Z. Brandino & I. C. G. Vieira. 1991. Social, economic and ecological consequences of selective logging in an Amazon froniter: the case of Tailandia. Forest Ecology and Management, 46: 243-273.

Umeki, K. 1995. Mdelling the relationship between the asymmetry in crown display and local environment. Ecological Modelling 82: 11-20

Relating crown asymmetry to neighbours and microtopography. Crown vector=2D vector from stem base with centroid of projected crown area.

UNDP/FAO 1983. Forestry development Brazil: project findings and recommendations. UNDP/FAO Field Document BRA/78/003, terminal report.

UNESCO 1973. *International classification and mapping of vegetation*. Ecology and Conservation Series 6. UNESCO, Paris, France.

Urban, D. L. , G. B. Bonan, T. M. Smith & H. H. Shuggart. 1991. Spatial application of gap models. Forest Ecology and Management 42: 95-110.

Uuttera, J., T. Tokola, & M. Maltamo. 2000. Differences in the structure of primary and managed forests in East Kalimantan, Indonesia. Forest Ecology and Management 129: 63-74

Valle, D., P. Phillips, E. Vidal, M. Schulze, J. Grogan, M. Sales, & P. van Gardingen. 2007. Adaptation of a spatially explicit individual tree-based growth and yield model and long-term comparison between reduced-impact and conventional logging in eastern Amazonia, Brazil. Forest Ecology and Management 243: 187-198

Valle, D., M. Schulze, E. Vidal, J. Grogan, & M. Sales. 2006. Identifying bias in stand-level growth and yield estimations: A case study in eastern Brazilian Amazonia. Forest Ecology and Management 236: 127-135

Van Daalen, J. C. 1993. The value of crown position and form as growth indicators in mixed evergreen forest. South African Forestry Journal 165: 29-35.

Diameter increment over 13 yrs correlated well with crown position and form scores for Cape forest tree species (e. g. *Olea, Podocarpus, Psydrax*). Growth of sub canopy species (e. g. *Cassine eucleiformis, Diospyros whyteana, Ocotea bullata*) not related to crown position (except *Ochna arbrea* which grew best in the shade), but was related to form for some species. Exposed crowns had better forms, if the species was one showing increment-crown correlation.

Van Gardingen, P. R. 1998. Impacts of logging on the regeneration of lowland dipterocarp forest in Indonesia. Commonwealth Forestry Review 77: 71-82.

Emphasis on effects on soil and seedling demography. 9 ha. PSP, with complete inventory ≥ 10cm DBH in central one. 10 tree/ha. removed. Sites in primary forest, manually logged, conventionally logged and RIL. Soil and canopy estimated on 5m grids. 38% of canopy removed and 52% of ground was covered by conventional logging debris or skid trails. Dipterocarp seedlings found along the margin of skid trails and in the undisturbed soil parts of felling gaps. One tree opened av. 390m^2 of canopy (270-540). NPLD seedlings taller in logged than undisturbed. Decline in mycorrhizae after logging. RIL, although less than conventional, still reduces mycorrhizae. No more than 2 adjacent trees (<650m2) should be felled, to prevent pioneer dominance.

Van Gardingen, P.R., M.J. McLeish, P.D. Phillips, D. Fadilah, G. Tyrie & I. Yasman. 2003. Financial and ecological analysis of managements options for logged over Dipterocarp forest in Indonesian Borneo. Forest Ecology and Management. 183: 1-29

Van Gemerden, B.S., G.N. Shu, & H. Olff. 2003. Recovery of conservation values in Central African rain forest after logging and shifting cultivation. Biodiversity and Conservation. 12: 1553-1570

Van Nieuwstadt, M.G.L, D. Sheil & K. Kartawinata. 2001. The ecological consequences of logging in burned forests of East Kalimantan, Indonesia. Conservation Biology 15: 1183-1186

Van Rompaey, R. S. A. R. 1993. Forest gradients in West Africa. PhD Thesis. Wageningen Agricultural University, The Netherlands.

Concentrating on forests in Liberia and Ivory Coast, and using mainly inventory data for larger trees, geographical and local changes in forest composition are described and discussed.

Van Vliet, N. & R. Nasi, 2008. Mammal distribution in a Central African logging concession area. Biodiversity and Conservation 17: 1241-1249

Van der Burgt, X. M. 1997. Explosive seed dispersal of the rainforest tree *Tetraberlinia moreliana* (Leguminsae-Caesalpinioideae) in Gabon. Journal of Tropical Ecology 13: 145-151.

Explosive dispersal from four *T. moreliana* trees to 60, 52, 51 and 41m. The nearest pods were 39, 32, 30 and 24m above ground. The tree produced 15000-20000 seeds; 1.5-2% in total was found more than 50m from the main tree. The ballistics of dispersal is discussed.

Van der Hout, P. 1996. Effects of logging with different intensities of low impact harvesting. Interim report. Tropenbos-Guyana.

Aims are to: Develop a LIH (low impact harvesting) system in Guyana, based around the CELOS harvesting system; study its effects on the residual stand at different intensities, compared to traditional logging; to develop post harvest silviculture; study economics of the above; and to develop growth and yield models. This report describes work 1992-1994 on the first two aims, describing vegetation, logging pattern and damage. It was too early, with only two measurements, to discuss tree growth and mortality.

The forest in the ('Pibiri') study area is rich in Greenheart ($^1/_3$ of basal area >40cm dbh) and locally dominated by other timber species as well, probably to a degree that makes the conclusions on some aspects of limited global applicability in tropical rain forest.

There are five components to LIH incorporated here. Enumeration and mapping of harvestable trees; climber cutting before harvest; selection of trees including an element of silviculture/ecology; directional felling to make a herring bone pattern; winching of logs from stump to trail. Four treatments were used. 1. 'Light' LIH (4 trees/ha.); 2. Moderate LIH (8/ha, or c. 25m^3/ha) as recommended under the CELOS system; 3. High intensity LIH (16/ha), being about the max. possible, with stems down to 40cm dbh; 4. As 2. , but succeeded by silvicultural treatment; 5. No intervention. Each treatment had a total of three replicates (i.e. 3 randomised blocks). Some samples were also laid in traditionally (uncontrolled) logging areas nearby.

Assessment of damage/efficiency, comparing controlled and uncontrolled logging, was along 3 strips (20x500 m). arranged in recording units (20x20m) within which all trees >20cm dbh (all species) were measured. Trees <5cm dbh were measured in a 5m wide strip. For other assessments, 140x140 blocks of 20 x 20m quadrats were assessed for all trees, all species, >20cm dbh. In the central hectare of quadrats, smaller trees were measured in nested subquadrats within each quadrat (5-20 cm dbh in 10x10m; within which2-5cm dbh in 5x5m; within which 1. 5m high to 2cm dbh trees in 2x2m).

Enumeration of trees ≥20 cm dbh was made before logging; all trees were enumerated after logging. BA felled was said not to be proportional to no. trees (N) felled because smaller trees had to be used at higher intensities. However, the relationship BA=0. 71+. 2N had a high R2 (0. 91). Other relations established were:

1. Area felling gaps (%)=-1. 99+8. 72 x BA
2. Area skid trails (%)=3. 89+1. 69 x BA
3. Remaining area (%) =97. 12-9. 52 x BA

Equation 2 has a low coefficient of determination (R2=0. 3).

The relation: The area of felling gaps (%) =1. 04+1. 82 x N has an R2 of 0. 79, which is said to be not quite as good a predictor as BA (whose r2 is not mentioned) as it takes no account of tree size. 1+2+3 is not quite 100% because of skid trails in felling gaps were 'double booked'.

With a BA <0. 8 (m2/Ha), skid trail area exceeds felling gaps, and 90% of the forest in unaffected. Above this, the opposite applies. At $4m^2$/ha 60% is unaffected. Topography is a better indicator of skid trails than BA felled, although a distinction is made between planned skid trails (3-7%) which did not correlate with BA, and unplanned ones (2% in light harvest) which were slightly more closely correlated with BA. Results are compared with those of Jonkers (87), Schmitt (89) and Hendrison (96), who all used different assessment techniques. Generally smaller % gaps were found for equivalent exploitation at lower intensities; and higher % gaps at higher levels. This is partly because natural gaps were included, and trees were generally smaller. However, LIH methods did reduce skidding damage. Gap areas (measured by 'projection of gap coordinates') occurred mainly above the stumps (due to smallish trees, regular canopy and directional felling).

The felling techniques used are extensively discussed. 89% of trees could be felled in the desired quadrant, an improvement on Hendrison (1990) because of the enhanced techniques. Winching short distances was often convenient. 20m winch distances were not implemented 49% of time due to impracticalities.

The frequency distribution of gap sizes is discussed. 7. 5% of the gaps (8 trees/ha LIH) or 14% (16 trees/ha) were 'unacceptably' large (ò500 M2). Mean gap size for single tree=176 m2; for 2 tree gaps=399 m^2 (n=12); for 3 trees=617m2 (n=3), suggesting 2 trees/gap is maximal if 500m2 is unacceptable. Gap area increased with intensity, surprising because no savings evident due to shared gaps.

Equations are also given for tree damage. One conclusion is that % completely undamaged trees after felling and skidding strongly correlates with, but is slightly higher than % area totally unaffected. Most damage to trees by skidding is classed as minor. % destroyed stems is in proportion to intensity, but % injury does not increase so. Accidental logging damage affected 15% of trees ò20cm dbh after a light harvest or 33% after a fourfold increase of BA extracted. In total 18%, 29% and 42% of commercial trees ò20 cm dbh were affected somehow after logging 4, 8 or 16 trees per hectare

Van der Meer, P.J., F. Bongers, L. Chatrou & B. Riera. 1994. Defining canopy gaps in a tropical rain forest: effects of gap size and turnover time. Acta Oecologia 15: 701-714

French Guiana: 18 gaps. Size affected by definition, but strongly correlated. Turnover time on forest floor 4-8 times lower than turnover time in the forest canopy.

Van der Meer, P.J. 1995. Canopy dynamics of a tropical rain forest in French Guiana. Thesis Landbouwuniversiteit Wageningen. 149 pp.

Van der Weert, R. 1974. Influence of mechanical forest clearing on soil conditions and the resulting effect on root growth. Tropical Agriculture (Trinidad) 51: 325-331.

Bulk density increases, especially nr. surface. Larger pores disappear. Citrus tree roots cannot penetrate so well.

Vanclay, J. K. , 1989. A growth model for North Queensland rainforests. Forest Ecology and Management 27: 245-271

Cohort model for 100 commercial species in 20 groups based on growth, habitat, volume relationships and commercial aspects. Increment and mortality patterns modelled for parent material, DBH and stand basal area, for each group. Recruitment composition predicted by site quality, stand basal area, and basal area of each group.

Vanclay, J. K. , 1990. Effects of selection logging on rainforest productivity. Australian Forestry 53: 200-214

Data from 212 PSPs provided no evidence of decline in rainforest productivity after three cycles of selective logging, as determined by difference between observed diameter increments and those predicted by theoretical functions. Trees with negative increments were excluded. No data from plots with two harvests – most had been logged once and had measurements which did not span logging activity. Gross biomass production not considered as 'reduction of production could be due to reduced occupancy of the site'. No evidence for long term decline found 'any decline does not exceed 6% per harvest'.

Vanclay, J. K, 1991a. , Aggregating tree species to develop diameter increment equations for tropical rainforests. Forest Ecology and management: 42: 134-168

Vanclay, J. K. 1991b. Mortality functions for North Queensland rain forests. Journal of Tropical Forest Science 4: 15-36

Vanclay, J. K. 1991c. Data requirements for developing growth models for tropical moist forests. Commonwealth Forestry Review. 248-271.

Vanclay, J. K. 1993a. Review of the forest inventory and management project. Annex 4 in Kemp *et al.* 1993. unpublished.

Vanclay wrote 'an analysis of the yield formula' whilst reviewing the project. In 5 years 5. 1% of trees will die. 40 yr survival is 1-(0. 949^8) = 34%. 16. 2% of surviving trees will advance one class in 5 years; 40 year probability of tree moving one or more class is (1-0243^8) =0. 757. 0. 757*0. 658=c. 50%. Yield formula is =0. 5Y+0. 2X; trees left=0. 5Y-0. 2X. (Y=>dbh; X<dbh). Assume no damage > felling limit, but 20% below it, leaving 0. 8X. In 40 yrs, 66% of trees>dbh limit will survive; 50% below will survive. At next harvest there will be 0. 33Y+0. 27X above the felling limit. The harvests will be equal if Y=. 33Y+. 27X (X=2. 5Y). If de Liocourt's Q=2. 5, harvests will be equal. Q can be calculated as (1-0. 5S)/ (0. 8G-0. 2S), where S is 40 yr probability of survival and growing a class; 0. 8 is prob. of surviving a harvest undamaged, and 0. 5 and 0. 2 from the yield formula. Serious omission of trees which move two size classes in 40 years. This Annex also includes a useful, brief summary of the status of the PSPs in Ghana.

Vanclay, J.K. 1993b. Environmentally sound timber harvesting: logging guidelines, conservation reserves and rehabilitation. Pp. 185-192 in Leigh H & M. Lohmann (eds.) Restoration of tropical forest ecosystems. Dordrecht: Kluwer Academic Publishers.

Vanclay, J. K. 1994. Modelling forest growth and Yield. CAB International, Wallingford UK. 312pp.

Textbook on how to model forests, especially from a commercial perspective.

Vanclay, J.K. 1995. Sustainable silvicultural systems: lessons from Queensland, Australia. Pp. 169-181 in O. Sandbukt (ed.) Management of tropical forests: towards an integrated perspective, Oslo: Centre for Development and the Environment, University of Oslo.

Vanclay, J. K. 1996a. Lessons from the Queensland rainforests: Steps towards sustainability. Journal of Sustainable Forestry 3: 1-27.

Vanclay, J. K. 1996b. Assessing thye sustainability of timber harvests from natural forests: limitations of indices based on sustainable harvests. Journal of Sustainable Forestry 3: 47-58

Four models demonstrate that maintaining a sustainable original harvest and sustainable disturbance harvest (defined as ratios successive harvests) are poor criteria for long term sustainable use, which should also consider the condition and vitality of the residual stand.

Between 1950-1985 eight estimates of sustainable yield vary ten-fold. Commercial logging ceased in 1988 two years after the attainment of sustainable yield. 'Invasion by weeds may be the first symptom a silviculture unsuited to the forest'

Vasconcellos, A., A.G. Bandeira, W.O. Almeida, & F.M.S. Moura. 2008. Termites that build conspicuous nests in two areas of Atlantic forest under different levels of anthropogenic disturbance. Neotropical Entomology 37:15-19

Vasconselos, H.L, J.M.S Vilhena & G.J.A. Caliri. 2000. Responses of ants to selective logging of a central Amazonian forest. Journal of Applied Ecology 37:508-514

Veenendaal, E. M. , M. D. Swaine, R. T. Lecha, M. Walsh, I. K. Abebrese & K. Owusu-Afriyie. 1996a. Responses of West African forest tree seedlings to irradiance and soil fertility. Functional Ecology 10: 501-511.

Veenendaal, E. M. , M. D. Swaine, D. Blay, N. B. Yelifari & C. E. Mullins. 1996b. Seasonal and long term water regime in a tropical moist semi-deciduous forest. J. Vegetation Science.

Veenendaal, E. M. , M. D. Swaine, V. K. Agyeman, D. Blay, I. K. Abebrese, & C. E. Mullins. 1996b. Differences in plant and soil water relations around a forest gap in West Africa during the dry season. Journal of Ecology 84: 83-90.

Two tree species (*Terminalia superba* and *Entrandrophragma utile*) are used to examine soil and plant-water relations in Tinte Bepo FR, Ghana. Only 4% & 7% seedlings survived the dry season in shade. 85% and 78% survived in the centre of gaps. Shaded seedlings suffered more drought stress. More water may be available in mid-gap because of greater variation in temperature. Leaf morphology (e. g. thin cuticle) due to shade may also be responsible. The correlation between shade tolerance and evergreenness is noted, possibly due to both shade-tolerance and drier conditions on forest floor.

Veldman, J.W., B. Mostacedo, M. Pena-Claros, & F.E. Putz. 2009. Selective logging and fire as drivers of alien grass invasion in a Bolivian tropical dry forest. Forest Ecology and Management 258:1643-1649

Veldman, JW; Putz, FE. 2010. Long-distance Dispersal of Invasive Grasses by Logging Vehicles in a Tropical Dry Forest. *BIOTROPICA* 42 (6):697-703

Verissimo, A. , P. Barreto, M. Mattos, R. Tarifa, & C. Uhl. 1992. Logging impacts and prospects for sustainable forest management in an old Amazonian frontier: the case of Paragominas. Forest Ecology and management 55: 169-200.

6 trees per hectare (38 m3 per ha.) 27 trees>= 10 cm dbh damaged per tree extracted (40m logging road and 600 m2 of canopy per tree). Scale map included.

Verissimo, A. , P. Barreto, M. Mattos, R. Tarifa, & C. Uhl. 1995. Extraction of a high-value natural resource in Amazonia: the case of mahogany. Forest Ecology and Management 72: 39-60

Poor observed regeneration of *Swietenia* and locally high logging damage (31 trees ≥10cm dbh damaged for each tree extracted).

Viana, V. M. & A. B. Anderson. 1990. Seed and seedling availability as a basis for management of natural forest regeneration. Pp. 95-115 in Anderson, A.B. Alternative to deforestation: steps towards sustainable use of the Amazon rain forest. Columbia University Press. New York USA.

Seed viability in *Vochysia maxima* (gap opportunist secondary species) in Belterra Brazil limited to 7 weeks after dispersal and <60m from parents. Seedlings persisted for >1 yr in shade, and decreased >50m from tree. A density of 1.5 trees/ha. is recommended for continuous regeneration.

Vidal, E. , J. Johns, J. J. Gerwing, P. Barreto & C. Uhl. 1997. Vine management for reduced impact logging in Amazonia. Forest Ecology and Management 98: 105-114.

Vine density three times denser in buillding phase than mature phase. Vines typically connected each tree to 3-9 other trees. Felling damage doubled if vines not cut. $16 /ha for vine cutting, but could be better focused.

Vieira, D.L.M. & A. Scariot. 2008. Environmental variables and tree population structures in deciduous forests of Central Brazil with different levels of logging. Brazilian Archives of

Biology and Technology 51: 419-431

Vieira, D.L.M., A. Scariot, & K.D. Holl. 2007. Effects of habitat, cattle grazing and selective logging on seedling survival and growth in dry forests of Central Brazil. Biotropica 39: 269-274

Vilanova-Torre, E; Ramirez-Angulo, H; Torres-Lezama, A. 2010. Carbon storage in the aboveground biomass as indicator of logging impact in the Imataca Forest Reserve, Venezuela. Interciencia 35: 659-665

Villela, D.M., M.T. Nascimento, L.E.O.C. Aragao & D.M. da Gama. 2006. Effect of selective logging on forest structure and nutrient cycling in a seasonally dry Brazilian Atlantic forest. Journal of Biogeography 33: 506-516

Vincent, G; Molino, JF; Marescot, L; Barkaoui, K; Sabatier, D; Freycon, V; Roelens, JB. 2011. The relative importance of dispersal limitation and habitat preference in shaping spatial distribution of saplings in a tropical moist forest: a case study along a combination of hydromorphic and canopy disturbance gradients. Annals of Forest Science 68: 357-370

Vonesh, J.R. 2001. Patterns of richness and abundance in a tropical African leaf-litter herpetofauna. Biotropica 33 502-510

Vooren, A. P. 1985. Patterns in tree and branch-fall in a West African rain forest vegetation. Forestry, Wageningen Agricultural University, The Netherlands.

Wadsworth, F. H. , B. R. Parresol & J. C. F. Colon. 1989. Forest increment indicators in a subtropical wet forest. In: Proceedings of the seminar on growth and yield in tropical mixed/moist forest. Kuala Lumpur, 20-24 June, 1988.

Wagner, T. 2000. Influence of forest type and tree species on canopy-dwelling beetles in Budongo Forest, Uganda 32: 502-514

Walker, L. R. 1994. The effects of fern thickets on woodland development on landslides in Puerto Rico. Journal of Vegetation Science 5: 525-532

Walker, L. R. , D. Harin, N. Fetcher, R. W. Myster & A. H. Johnston. 1996. Ecosystem development and landslides in the Caribbean. Biotropica 28: 566-576.

Walsh, P.D., K.A. Abernethy, M. Bermejo, R. Beyersk, P. De Wachter, M.E. Akou, B. Huljbregis, D.I. Mambounga, A.K. Toham, A.M. Kilbourn, S.A. Lahm, S. Latour, F. Maisels, C. Mbina, Y. Mihindou, S.N. Obiang, E.N. Effa, M.P. Starkey, P. Telfer, M.Thibault, C.E.G. Tutin, L.J.T. White, & D.S. Wilkie. 2003. Catastrophic ape decline in western equatorial Africa. Nature 422: 611-614

Walsh, P.D., P. Henschel, & K.A. Abernethy. 2004. Logging speeds little red fire ant invasion of Africa. Biotropica 36: 637-640

Waltert, M., Lien. K, Faber, & M. Muhlenberg. 2002. Further declines of threatened primates in the Korup Project Area, south-west Cameroon. Oryx 36: 257-265

Webb, E.L. 1998. Gap-phase regeneration in selectively logged lowland swamp forest, northeastern Costa Rica. Journal of Tropical Ecology 14: 247-260

Webb, H. R. 1948. Mahogany regeneration in the Budongo forest, Uganda. East African Agricultural Journal 13:181.

Webb, L. J. , J. G. Tracey, & W. T. William. 1972. Regeneration and pattern in the subtropical rain forest. Journal of Ecology 60: 675-695.

Weber, B ., A. Veder, H. Simons-Morland, L. White & T. Hart. (eds.). African rainforest ecology and conservation, New Haven: Yale University Press.

Weisenseel, K., C.A. Chapman & L.J Chapman.1993. Nocturnal primates of Kibale Forest: effects of selective logging on pro-simian densities. Primates 34: 445-450.

Welden, C. W. , S. W. Hewett, S. P. Hubbell & R. B. Foster. 1991. Sapling survival, growth and recruitment: relationship to canopy height in a neotropical forest. Ecology 72: 35-50.

50 ha. plot Barro Colorado, Panama; 3 yrs of data. Extensive data on mortality, etc. In most species, sapling survival is lower in low canopy sites than in high canopy sites. Canopy edge trees are more likely to fall into the gaps, rather than forest. Low canopy sites had the faster growth in 57% of species. 43% showed no difference. Biggest variation between canopy height categories were among rare and occasional species.

Wellman, F.L. 1972. *Tropical American plant disease - Neotropical phytopathology problems*. The Scarecrow Press, Metuchen, New Jersey.

Wells, K., E.K.V. Kalko, M.B. Lakim, & M. Pfeiffer. 2008. Movement and ranging patterns of a tropical rat (Leopoldamys sabanus) in logged and unlogged rain forests. Journal of Mammalogy 89: 712-720

Wells, K., E.K.V., Kalko, M.B Lakim, & M. Pfeiffer. 2007a. Effects of rain forest logging on species richness and assemblage composition of small mammals in Southeast Asia. Journal of Biogeography 34: 1087-1099

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Werner, FA. 2011. Reduced growth and survival of vascular epiphytes on isolated remnant trees in a recent tropical montane forest clear-cut. Basic and Applied Ecology 12: 172-181

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Wilson, M. F. 1993. Dispersal mode, seed shadows and colonization patterns. Vegetatio 107/108:261-280.

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Wong, J. L. G. 1994a. Timber species classification and the assessment of exploitation problems. Unpublished. Ghana Forestry Dept/ FIMP Discussion paper 4.

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Wong, J. L. G. 1994b. Study of the implications of Forest Protection proposals. Definition of scenarios. Unpublished. Ghana Forestry Dept/ FIMP Discussion paper 5.

Initial results of study of implications of protection proposals in Hawthorne & Abu Juam (1993). Reinterprets the designation 'provenance protection', such that each Scarlet and Red Star species gets (at least) a single provenance protection site, and intact forest is treated separately. {Subsequent interpretation inevitably has lead to only a single site being chosen for each red/scarlet species, thereby hardly implementing the original principle of general provenance (rather than one token provenance) protection for each species}. Proposal also to base choice of 'intact' forest sites on basis of Basal Area from inventory results. Recommends additional specific category of protection for shelterbelts, including 22000 ha of shelterbelts not otherwise protected or destroyed, in spite of the fact that most of this area should have been subsumed under fire protection. Includes initial figures for revised areas under each large- grained protection category.

Wong, J. L. G. 1995. Timber yields from the forest reserves of Ghana: An analysis of the implications of sustainable forest management. Unpublished. Forest Inventory & Management Project, Forestry Dept. , Kumasi, Ghana. 32 pp.

Investigation of the implications for timber production of: protection of blocks of forest (large-grained protection as in Hawthorne & Abu Juam, 1996); and various components of 'fine-grained' protection, such as yield control and protection of small blocks of forest. 760,000 ha of forest are well-stocked and suitable for timber production.

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Preliminary analysis of PSP data suitable a review of the Interim Yield Formula, describing cleaning and analysis of PSP data from 61 PSPs (second enumeration) from Atewa, Baku-Supon-Wawahi, Pamu Berekum, Mpameso, Muro, Bia, Tano Nimiri, Tano Anwia, Draw river and Ebi shelterbelt FRs. 4-8% of these data had to be removed from the data-set due to errors. Stem turnover, balance between recruitment and mortality, about zero overall. Mean net volume increment of commercial species was about 0. 8m^3/ha/yr (total of 2 for all species). Plots with <20m^2/ha basal area have reduced net increments. Observed crown and bole damage strongly related to mortality and lower growth rates. Mortality is 12% for severely damaged trees, or 1% for undamaged. Many plots nearer (<100m) to reserve boundaries have higher mortalities than any of those analysed from deeper in the forest.

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Yeom, F. B. C; 1984. Lesser-known tropical wood species. *Unasylva* Vol. 36:145, 2-22. FAO. Rome. Italy.

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Trees on the edge of gaps are more likely to fall into pre-existing gaps than in other directions (Barro Colorado, Panama). Trees not at gap edges were more likely to fall away from nearest

neighbours. Gross asymmetries of crown are the rule, and most gap edge trees are asymmetrical. Non gap trees tend to be asymmetrical away from nearest neighbours. Gap regeneration is therefore retarded by re-falls of lopsided trees. In 5yrs of data of 50ha plot, sites within larger gaps were significantly more likely to be re-disturbed by secondary tree-falls than elsewhere. Hence tree-fall gaps may be more persistent than thought. 127 trees with >20 cm dbh in a 0. 8 ha subplot were mapped, showing crown shape along each of eight compass points. Crown asymmetry: 'a line was drawn through the bole perpendicular to a line between the centre of crown area and the base of the bole. The areas on either side of this line were calculated with an area meter, and absolute asymmetry calculated as the greater of the two areas divided by the total area.

Yorke, C. D. 1984. Avian community structure in two modified Malaysian habitats. Biological Conservation 29: 345-362.

Yusop, J. 1994. Effects of selective logging methods on suspended solid concentration and turbidity level in streamwater. Journal of Tropical Forest Science 7: 199-219.

Traditional, and more recent, less damaging selection system compared in Berembun FR, Negri Sembilan, Malaysia. Comparison made with three year calibration period and 5 years post treatment. After year 1, 12x or 9x, continuing until year 5, but varies with catchment.

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Zoysa, N. D. de, C. V. S. Gunatilleke & I. A. U. N. Gunatilleke. 1991. Comparative phytosociology of natural and modified rain forest sites in Sinharaja MAB reserve in Sri Lanka. Chapter 10 Pp. 223-233. in Gomez Pompa *et al.*,

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