Effects of the construction of logging skids on forest structure, diversity and regeneration.

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Chapter 1: INTRODUCTION AND LITERATURE REVIEW

1.1 RATIONALE FOR THIS STUDY

There are around 40 million hectares of tropical peatland remaining in the world. Peat swamp can be found in the Amazon, the north coast of South America, Tropical Africa and some of the Caribbean islands. However, the tropical peatlands of the Far East are the most extensive, understood and economically important. Tropical peatland is an important ecosystem, unfortunately it is also endangered, as are many of the worlds remaining natural ecosystems. The principle characteristic of this habitat is the peat soil. This has been defined as a soil in which the organic matter shows a loss on ignition greater than 65% (Whitmore, 1984).

Tropical forests are being cleared, burned, logged, fragmented and overhunted on scales that lack historical precedent (Gascon et al, 1999). These peatland forests are thought to be less diverse than dry land forests but they are undoubtedly an important reservoir of biodiversity, including a few (explained by the habitats' relatively young age of around 11,000 years) tree species endemic to such habitats e.g. *Conystylus bancanus*. They are pharmacopoeias of irreplaceable products, including medicines and disease resistant germplasm for many of our vital crops.

The processes of habitat loss and fragmentation go hand in hand. This creates a huge threat to the biodiversity of such areas, which are typically the most diverse and ecologically complex of land communities (Myers, 1988), occupying ~7% of earth's surface and sustaining over half of the planet's life forms (Wilson, 1988).

1.1.1 Functions of Tropical Peatlands

Peatlands are also a hugely important store of carbon, locking up carbon for thousands of years. It has been estimated that the peat bogs of Indonesia alone may hold up to 50 billion tonnes of carbon. That is the equivalent of around eight years worth of fossil fuel emissions. Many tropical peat bogs are important in maintaining the stability of watersheds and rivers. Recent floods in Central America and China were amplified by deforestation in the watershed areas.

The vital roles that peatlands play in carbon cycling and sequestration are lost under land drainage and conversion to any other land use. The threat to the remaining forests is further exasperated by the expansion of trade liberalisation and international free trade agreements such as NAFTA (North American Free Trade Agreement) which are promoting further foreign investment in the tropical resource extraction industries (Bowles *et al*., 1998).

1.1.2 Politics

One of the main problems involving peatlands is their location, much is located within under developed countries, often with corrupt and ill advised legislators. Didia (1998) found that there was a strong negative correlation between the level of democracy and the rate of tropical deforestation. Many sector developments take place without adequate prior environmental assessments. Consequently, many of these schemes are unsustainable and fail. A clear example of this was the one million hectare Mega Rice project of Central Kalimantan between 1996 and 1998, which resulted in the clearance of over 400,000 hectares of tropical peat swamp and the construction of over 4,500 km of drainage and irrigation channels. These also provide easy access to the interior for the 15,000 displaced farmers and local populations, further exasperating the overexploitation of the peat swamp forest. The land proved to be of little agricultural use and now lies redundant and highly prone to fires.

In Amazonian countries, population size within the basin explains about two-thirds of the variation in mean rates of rainforest destruction (Laurance, 1998). This was amplified through hundreds of forest colonisation projects. A similar problem occurred in Indonesia with the massive transmigration programmes implemented to reduce population pressures in urban areas. This has a number of obvious negative effects; it was a huge contributor to the Indonesian economic crash. This economic instability destroys incentives for long term resource management and promotes short-term exploitation. Westoby (1978) argued that socio-economic factors, such as poverty and un-equal land tenure, are more important in determining the rates of deforestation.

1.1.2 Formation of Peatlands

The formation of peatlands is believed to have been initiated 11,000 years ago, at the end of the last glaciation. The melt waters carried fine sediments towards coastal areas, which were deposited as levees and flood plains. Behind these, back-swamps began to develop. This caused the advance of the coastline, backing up of fresh waters and mangrove swamps to become less saline, providing an ideal physiographic setting for the formation of peat swamps. The high sulphide and salt content of the underlying clay is toxic to the micro-organisms that would normally decompose falling plant debris (Anderson, 1964). It is interesting to note that there are no peat swamps on the island of Java where the rivers drain base rich, volcanic soils.

1.2 SOIL DEGRADATION

Soil damage incurred during logging or clearing reduces the growth of any regeneration. One of the most detrimental effects of deforestation upon the underlying soils is a loss of anchorage. Without the forests to stabilise the soils erosion is prolific. The surface runoff from recently constructed skid trails may be an order of magnitude greater than that of the surrounding forest (Croke *et al*., 1999). During the 1980's rivers in Sarawak were heavily silted up. This took a heavy toll upon the local fisheries (Chin *et al*., 1992) and obviously affected the well being of many families dependant upon the river.

Soils that have been converted to agricultural use tend to have a considerably higher bulk density with an associated loss of porosity. This is because of tillage and other compaction incidents. The persistent effect of machinery compaction of surface soils was illustrated by Croke *et al*. (2001). Their study showed no significant recovery over a five year period. Pinard *et al*. (2000) showed that even after eighteen years skid trails might be impoverished in small woody stems. This causes reduced water infiltration, soil moisture availability, aeration and rooting space (Greacen and Sands, 1980). Therefore, during heavy rains, seeds and organic matter may be washed away and displaced. This does not reduce the total soil organic matter content, just its distribution, thereby creating ideal habitats for pioneer vegetation (Guariguata and Dupuy, 1997). The level of canopy cover, sapling density, litter composition and depth are all influential in the retention of soil. Such characteristics reduce the erosive power of raindrops and create a surface roughness, which minimises soil detachment and creep.

However it has been argued that the processes of topsoil displacement and profile disturbance are more damaging to plant growth than compaction. This highlights the importance of incorporating topsoil retention into forest management plans.

Management generally results in more alkaline soils than typical forested soils. The overall nutrient status of managed soils is generally lower (Figure 1.1) due to over exploitation, increased annual cropping and high maintenance GM (genetically modified) crops. Without adequate financial input this eventually renders the soils infertile, and subsequently reduces the chances of any successful forest regeneration.

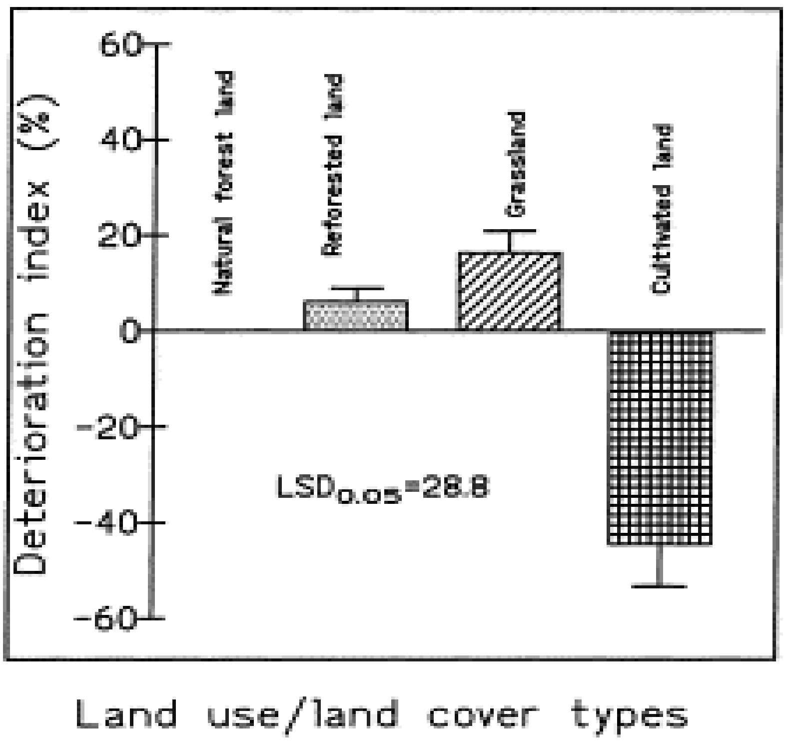


Figure 1.1. Deterioration index for different land use/land cover types in a tropical forest ecosystem in Dhaka division, Bangladesh. Each deterioration index was calculated as the sum of the percentage

deviations of P_{δ}, AS, C_{org}, N_T, C_{TMB}, C_{AMB}, qCO_2:A, C_{FA} and C_L from their respective values under natural forest. (Source: Islam & Weil, 2000)

1.3 SKIDS AND COMMUNICATIONS NETWORKS

Although logging infrastructure comprises only a small area of a total stand, it may provide introduced species with a primary route to the interior forest. This may ultimately result in changes of plant richness and stand composition, especially where clearances are indiscriminate. This increasing post-logging competition between trees of commercial value and those of no financial value is an area of grave concern in the tropical forests of Bolivia (Jackson *et al*., 2001). In order to ensure a sustainable commercial tree stand a number of control treatments have been adopted.

During logging processes it has been commonly noted that much of the residual stand sustains a high level of potentially fatal damage. The most common types of damage are uprooting of stems, stem wounds to the cambial layer and bark scrapes. Jackson *et al*. (2001) found that significantly less damage was incurred along skid trails than along logging roads and suggested that residual damage sustained in felling gaps is positively related to the diameter at breast height (dbh) of harvested trees. This is important for future concession designations.

1.3.1 The Threat of Forest Fires

The loss of forest leads to a reduced level of evapotranspiration, which results in lower humidity and rainfall, higher surface temperatures and ultimately a higher susceptibility to forest fires. This has been evident in Indonesia over the last decade. Rainfall patterns will also be altered due to an increase in surface albedo with deforestation and desertation.

Logging is generally a selective practice with the removal of more desirable tree species (hard woods on the commercial scale – ramin, mahogany). This has a large impact upon the remaining residual forest stand including a 20-40% reduction in canopy cover and tree density and an increase in the potential ground fuel for subsequent fires (Johns et al. 1996). The opening of the canopy increases the incidence of solar radiation on the forest floor; this creates a reservoir of dry fuel. Trees remaining in the residual stand, which sustained damage during logging, are more likely to die during a burn. Therefore fire in heavily logged stands is likely to result in much higher tree mortality than any previously observed burns.

The threat is multiplied by the fact that many clearances occur adjacent to previously converted forest where burning is used in pasture maintenance this also provides a likely source of ignition. Therefore the threat of fire is in a positive feedback cycle, where an initial burn increases the risk of further fires. Woods (1989) found that mortalities caused through fire were generally higher in logged forests than in unlogged forests. This is supported by observations made by Page et al. (1997) looking at the location of burn sites after the fires of 1997 in Central Kalimantan. They found that 70% of the fragmented and 29% of the logged over peat swamp forest had been destroyed by fire but only 5% of the pristine peat swamp forest. This is probably because saplings are more sensitive to burning and increased drainage associated with peat disturbance. Experience from the Amazon rain forest suggests that a regrowth period of around four years allows a forest to regain its fire resistant characteristics (Holdsworth and Uhl, 1997). The reason for this prolonged recovery period is that the seed banks, which potentially provide the source of any regeneration (Swaine and Hall, 1983), may also be lost during burning.

Statistical differences in success were found between regeneration modes after forest fires in Venezuela (Kammesheidt, 1998). Resprouts were more successful than seed established individuals. Studies in Paraguay have shown that resprouts contributed to the regeneration of all lower canopy species and approximately one-third of total regeneration. This was also apparent after the fires in Kalimantan of 1997, which were promoted by the drainage and clearance of the area. This is the opposite of logged stands unaffected by fire. The fire probably kills off any above ground meristematic tissue, whilst stimulating the growth of buds and tissue below the surface. This will obviously disturb the stand composition. The resprout mechanism of regeneration has probably evolved to fill the niche in the low radiation environment of the forest floor where an established root system provides sufficient assimilates to support resprouting. Therefore it is already in existence under the surface prior to fire. Larger trees also benefit from this initially but are eventually out competed by the establishment of seed pioneers (Stocker, 1981). The seed dispersing pioneer species become less prominent in the seed rain as parent plants are outcompeted and ultimately killed by woody species.

1.3.2 Reduced Impact Logging

Employing reduced impact logging (RIL) techniques can reduce the impact of skidding ('snig' track – Australian) and other logging communications. Successful implementation has been observed in the Bolivian rainforests (Jackson *et al*., 2001). This requires the incorporation of pre-harvest tree inventories, planned placement of roads and skids trails, vine cutting and directional felling. Some modern techniques involve the separate handling of topsoil during excavation and rehabilitation. Some decompacting of skid road running surfaces has also seen some success (Dykstra & Curran, 2000).

As well as reducing the impact of forest management upon the forest, RIL may also improve the efficiency of timber abstraction. Careful planning of tree felling in parts of Amazonia has resulted in a 15% increase in productivity. In the absence of such planning, 26% of timber felled was wasted due to poor felling techniques and misplacement! In the planned tree felling, there was only a 1% wastage (Barreto *et al*., 1999). Johns *et al*. (1999) estimated that profit margins of logging companies that switched to RIL techniques would actually increase.

Skid road rehabilitation was made mandatory in British Columbia in 1995, with the implementation of 'The Forest Practices Code of British Columbia Act' (FPC). This was enforced on all skid roads by December 1999. This required the restoration of slope hydrology and site production (Dykstra, 2000).

More and more rehabilitation is becoming apparent in the aftermath of forest management. The motivation behind this is the fact that rehabilitated skid trails will support future crops of merchantable quality timber. However, a number of barriers still stand in the way of effective global management. Knowledge is not freely transferred to landowners and important forestry regulations are not enforced which results in apprehensive investment into forested land, as tenure is often insecure.

1.4 LOGGING EXPERIENCE

Post-logging canopy cover was negatively correlated to the number of trees extracted per hectare during controlled selective logging in the lowland swamp forest of northeast Costa Rica. The stand basal area within the study site was reduced by approximately 18.3% with 17.6% of the residual stems left damaged or killed (Webb, 1997). It can be assumed that such effects would be greater under illegal extraction due to the unplanned, unsupervised nature of such operations. Selective logging is obviously more ecologically sound than clear felling but it is potentially just as damaging as it remains unselective in the damage it does to the saplings which form the next generation of trees. This was illustrated in Malaysia by a strong correlation between ranked basal areas before and after logging for the twenty most common genera of trees (Johns, 1988).

The number of trees removed does not reflect the impact of logging. It is often far worse as logging communications tend to cause most of the disturbance. In East Malaysia logging concessions typically quote that 8-15 trees are removed per hectare but that this requires 15-40% of the area to be traversed by bulldozer. Verissimo *et al.* (1992) found that 218m^2 of ground surface was disturbed for each tree removed in the Brazilian Amazon. Another study indicates that 20% of the land area in Indonesia is deforested for the construction of roads and increasing to 30% if skid trails are included (Hendrison, 1990).

In a study carried out in the Sabah rain forest, Malaysia, it was concluded that by employing reduced impact-logging strategies the level of disturbance could be reduced (Pinard *et al.*, 2000). Roughly 17% of a 450 hectare experimental area was disturbed under uncontrolled conventionally harvesting (roads and skid trails) and roughly 6% where reduced impact guidelines were implemented. This included measures for reducing the amount of topsoil bladed off along skid trails and a reduction in mechanised removal by employing skylines (Miller and Sirois, 1986), helicopter (Blakeney, 1992) or manual skidding techniques.

Plate 1.1. An illegal logging 'gang' using a manual skid – 15 men in this instance. No heavy machinery is involved in the abstraction of timber from the forest, probably due to a lack of funding and inconspicuousness. Timber is dragged with ropes along the wooden – railway like – structure to a previously excavated canal. During the wet season, canals become flooded and timber is floated out to a major water coarse (Sungai Sebangau in this case), where it is eventually bound and transported by lorry to storage sheds where it is processed (Plate 1.2).

Minimising the soil and stand disturbance during logging appears to allow vegetation to regenerate more successfully, with greater species richness of woody stems. It has also been suggested that after a period of 18 years, tree regeneration on skid trails remains less than the residual forest. Plumptre (1996) suggested that a period of around fifty years is required for a forest to recover to pre-logging conditions, based upon a study of the Budongo forest, Uganda.

The edges of the skid trails and adjacent forest tend to have a greater number of saplings, greater species richness and canopy cover than the skid tracks. However, the long-term fate of these trees on the compacted soils is still unknown as, in some forests, changes in soil properties brought about through logging may persist decades after logging (Van der Plas and Bruijnzeel, 1993). However all of the alternatives to ground skidding tend to be more expensive, except for manual skidding (Plate1.1), which is generally not commercially viable due to the manpower and numbers required.

Plate 1.2. A storage shed in the village of Maker, one of many which lie on the banks of the Sungai Sebangau to the south of Setia Alam.

1.5 KALIMANTAN

Around 60% of the world's Tropical peatland are in south-east Asia. The Philippine archipelago, Indochina, Malay Peninsula, India, Java and Lesser Sundaes have been heavily deforested (>75%), while Borneo, Sumatra, Sulawesi and New Guinea retain over half of their forest cover (Dinerstein, 1999). There are an estimated 17,000,000 hectares of tropical peat swamp forest in Indonesia, of which 9,700,000 hectares occurs on the east coast of Sumatra and 6,300,000 in Kalimantan; the rest is in Sarawak and Malaya. There are approximately 6.8 Mha located on the coastal lowlands of Kalimantan (Rieley *et al*., 1996). The forests of central Kalimantan are the most studied of them all. One of the largest of these forests is located in the predominantly peat-covered catchment of the Sungai (river) Sebangau. However, there are numerous granite outcrops forming islands within the catchment. These areas exhibit very different characteristics to the rest of the forest but they have not yet been studied to any great extent. The entire catchment covers an area of around 5000 km^2 between the Sungai Kahayan and the Sungai Katingan (Figure 2.1).

Peatlands generally exhibit a convex shape, due to the nature of their genesis. The peat has an underlying substrate composed of alluvial clays and sand. The depth and nutrient status of the peat form unique catenary steps. This is mirrored in a hydroseral vegetation pattern and clear zonation, i.e. riverine forest (clearly visible in Figure 2.2 (floodplain)), marginal mixed peat swamp forest and low pole forest through to tall pole forest at the centre, in a series of concentric circles.

Much of the riverine forests in the Sungai Sebangau catchment has been lost to burning, agricultural practices by nomadic river gypsies or huge government funded projects. This has left many banks stripped of any anchorage and susceptible to erosion and prone to breaching. The dark heavily silted up waters reflect this. Common, veracious, fast growing species such as Cyperaceae (sedge) and Pandanaceae (pandan) now dominate the banks. These are prominent at most areas of disturbance throughout the forest. The surface waters forming pools and channels throughout the forest are generally of an ombrogenous nature. The only input is that of rainfall, hence the chemical composition is very similar to that of the rainfall, i.e. acidic and a similar low level of macro-nutrients.

1.5.1 An Overview of the Vegetation within the Sungai Sebangau Catchment

Prior to any clearance, the riverside vegetation is comprised mainly of the tree *Shorea balangeran*. This is the tallest of the riverine vegetation reaching heights of up to 35 metres.

Between 1-3 km this riverine forest (Figure 2.2) begins its transition to a mixed peat swamp forest. This change comes about because of the change in topography. It is beyond the highest level of wet season, river flooding with surface water within hummocks/pools rising and falling with the water table. Under water logged conditions the pools become interconnected via channels and rills, which drain the water off towards the river. The speed at which water is channelled to the river has been modified through the construction of timber canals, which are used to float timber out of the forests and provide irrigation to agricultural projects.

The majority of this forest grows to around 35 metres in height. The stand is composed of a greater number of species than the riverine forests. This is mirrored by a greater number of commercial tree species including *Calophyilum sclerophyllum, Dactylocladus stenostachys, Gonystylus banangus* and *Shorea balangeran*. This obviously makes it one of the more desirable areas to exploit. The under-storey can be divided into two distinct layers. The first is a closed layer at a height of between 25-30 metres and the other at 7-12 metres is more open. They are comprised of younger specimens of the canopy layer along with a number of species from the genera *Diospyros, Eugenia* and *Garcinia*. Under this, the light starved ground is carpeted by a mix of saplings, sedges, shrubs, herbs and some ferns (relatively few compared to lowland dipterocarp forests). There are also a number of insectivorous pitcher plants (*Nepenthes rafflesiana*), rattans (*Calamus* spp) and orchids (*Bulbophyllum acuminatum*) in this part of the forest. The presence of plants exploiting alternative sources of nutrition, such as the insectivorous pitcher plants suggests that the peats have a lower nutrient status than those in the riverine forest.

At a distance of around 3km from the river edge is the medium pole forest. From here through to the low pole, the forest canopy is generally lower at around 25-30 metres as well as having less distinct canopy layers. Species composition remains much the same, hence it is also heavily exploited through logging. However the ground vegetation is very much less diverse, with an almost 100% pandan coverage occasionally disrupted by the presence of pneumatophores and a dense mat of roots.

The medium pole forest grades into the low pole forest at approximately 6km from the riverbanks. This contains very few commercially desirable species and also has a much more undulating, wet forest floor making timber abstraction very difficult. There is a lower density of trees here with less definition between canopy layers, the tallest trees reach around 20 metres. The forest floor here is again composed primarily of pandan, owing to the wet conditions and comparatively high levels of irradiation.

The central area, at around 12km from the riverbanks, of the peat dome is occupied by the tall interior forest, which proceeds over the watershed for a further 13km. This is obviously the most elevated part of the catchment. The peat reaches a depth of around 12 metres here, high above the water table for most of the year. Because the peat is dry for much of the year it becomes aerated and more hospitable to micro-organisms. Therefore decomposition is greater and nutrients are recycled far more efficiently. This may explain the relatively high forest complexity here. This is accompanied by the absence of pneumatophores.

The forest in the tall pole exhibits many characteristics of a dry land forest, with a flat dry forest floor. This tall central forest is unique as it does not conform with any previously observed patterns of peat dome vegetation within south-east Asia. At all other study sites, tree height is negatively correlated with peat depth. The majority of species found in the centre of the Sungai Sebangau catchment are not present at the centre of the Sumatran peat forest. There are also consistently more trees per unit area in the Sungai Sebangau catchment peat forest.

The transition between the low pole and tall pole forest is the most obvious in the forest, with trees in the tall pole reaching heights of 45 metres. The ground flora is also very different to that of the low pole. The peat here is drier throughout the year, and a dense canopy limits irradiation. Therefore pandan no longer prevails as the primary ground cover but there is a greater abundance of climbers and epiphytes. The forest here also contains a great number of commercial tree species, and is subjected to an even higher intensity of logging than the mixed peat swamp forest.

The canopy in the tall pole forest can be subdivided into three layers. The tallest layer is composed of a sparse number of tall emergent trees at around 35-45 metres in height. Between 15-35 metres is the middle canopy, and below this is the sparse under canopy. This contains some additional tree species.

1.5.2 The Current Situation and Problems in Kalimantan/Indonesia

Kalimantan is the Indonesian part of Borneo, the third largest island in the world. Kalimantan occupies the southern part, an area of around 550,000 km^2, half of which is estimated to be under semi-natural vegetation. Central Kalimantan is the largest province at over 152,000 km^2. The forest here is very rich botanically, including over 84 families and 370 genera (Whitmore *et al*., 1990). This is despite the heavy logging of at least 1000 timber sized species (Argent *et al*., 1997) since the late 1960's, which has and continues to decimate large areas of lowland forest around the peat swamps. Landsat images taken between 1997 and 2000 indicate a 44% increase in the level of logging within a 2.5 Mha area in Central Kalimantan. The majority of this is illegal logging as most concessions have come to the end of their 20 year concession licenses. Illegal logging has become so rampant in this province that regeneration of selectively logged forests may be unlikely (Rijkse and Meijaard, 1999). Chambers *et al*. (1998) proposed that timber stands would need an unrealistically long interval to recover, as rainforest trees are ancient. In the Brazilian rainforest, it has been noted that repeat extractions result in the removal of nearly all marketable species, even those previously deemed too small. Therefore polycyclic logging regimes are not sustainable.

Illegal loggers, who are less sympathetic to the forest, also reduce the success of any polycyclic logging through the theft of the next crop of trees. Much of the illegal logging is fuelled by international demand as the export of logs from Indonesia was banned in 1985. The concessions between the Sungai Sebangau and the Sungai Katingan expired in 1996. These contracts were issued on trees measuring over 6-inches/15.54 cm dbh (diameter at breast height, 1.3 metres). This is another example of poor management, as other concessions have maintained larger trees by imposing a larger minimum dbh. In the lowland swamp forest of Costa Rica, 70cm dbh was imposed as the minimum. By retaining smaller trees, the next harvest will be more successful and it also allows some habitat stability.

The population of Kalimantan was 1,805,400 in the year 2000 and consists mainly of the animalistic Dayaks (meaning 'people of the interior'). These indigenous people commonly practice slash and burn shifting agricultural techniques (ladang) but also utilise non-timber forest products (NTFP's). In 1990 the logging industry accounted for 5% of Indonesia's total economic output and 6.3% of the countries employment. Considering that much of the work force is involved in subsistence work, deforestation seems like a big price to pay for this rather small economic return. The staple diet is rice, which was obviously the motivation behind the ill-advised 'mega rice' project.

1.6 THE FUTURE OF KALIMANTAN

There are still large areas of peat swamp forest remaining in a relatively intact state across Kalimantan. Unfortunately much of this has already been earmarked for timber extraction. This will probably be achieved using low technology, cheap, selective logging techniques such as manual skidding.

A number of individual conservation based organisations are now working in Central Kalimantan in an effort to persuade the government that it is an area worth preserving. Protection is needed promptly as Indonesia has the longest list of threatened species in the world, even greater than Brazil's.

Hamilton (1997) recognised five categories of environmental disturbance caused by the current logging system (natural forest logging) in Kalimantan:

1. Deforestation.
2. Erosion and siltation.
3. Changes in water flow rates and water quality.
4. Pollution of forest lands from fuel oils, chemicals and human garbage (Plate 1.3).
5. Impacts on wildlife, including habitat fragmentation, depletion of food sources and loss of diversity.

The alternative to natural forest logging is to clear land and set up monocultures of fast growing trees and adopt sustainable rotations. During the fuel wood crisis in Kenya (1980's) many eucalyptus plantations were established. Davies (1989) estimated that there is a total of 19.8 million hectares of land suitable for plantation establishment on the outer islands of Indonesia (beyond Java and Bali). This would ameliorate the short-term impacts upon the indigenous forests.

Plate 1.3. A recently deserted logger's 'pondoc' adjacent to transect 2. The water in the foreground is a canal that was also constructed by the illegal loggers. The area immediately surrounding the 'pondoc' is strewn with litter. This included food wrappers and empty fuel cans.

Groups currently working in the area include small research orientated groups such as 'OU-Trop' and large-scale environmental bodies such as the 'WWF'. However, plans for its future are certainly not ecologically sound. It has been proposed that a 2.8 million hectare economic zone or 'Kapet Das Kakab', incorporating the mega rice project area, be developed. This area will be converted to both food crops and plantations, with an emphasis upon oil palm and rubber. This would have severe effects upon the fauna and flora of the area, with large-scale irreparable damage.

2.1 SITE DESCRIPTION

The study site was near the field station based at 'Setia Alam' in the Northeast of the 9000km^2 Sungai Sebangau catchment (Figure 2.1). This is approximately 20km south-west of Palankaraya, the provincial capital of Central Kalimantan. Setia Alam is in the forest about one kilometre from the Sungai Sebangau, in the transition zone between riverine forest and mixed peat swamp forest (MPSF).

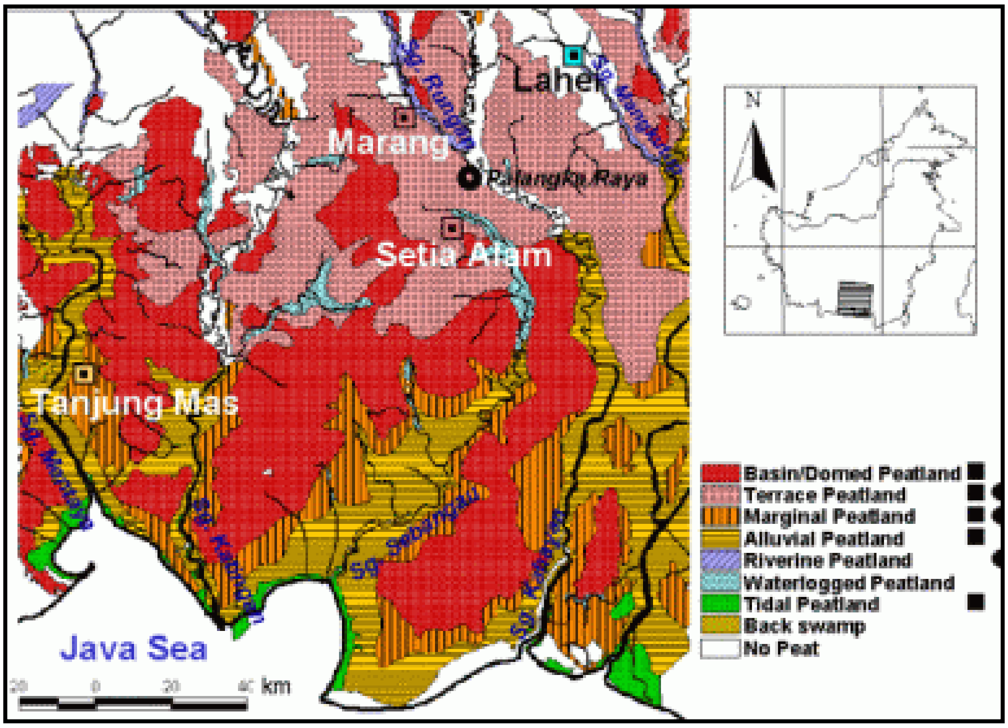


Figure 2.1. The main map shows the position of Setia Alam in relation to Palangka Raya and the smaller map indicates the location of the Sungai Sebangau catchment (area enclosed by the major rivers Katingan and Kahayan) in relation to the island of Borneo. The location and type of peat deposits are shown. It clearly occurs predominantly around coastal areas (this is explained by the process of peat bog formation).
(Source: http://wwwgeo.ees.hokudai.ac.jp/memberhome/~shima/ppframe.htm)

The MPSF occurs between 1 and 3km from the banks of the Sungai Sebangau (Figure 2.2), beyond the highest levels of wet season river flooding. In the dry season the water table falls below the surface of the hollows and by the end of the dry season, there is usually no water in the pools or outflow streams. The number of logging canals greatly influences the time of dormancy of these water sources.

The MPSF is located on the incline of the convex peat deposits, at an elevation of approximately four meters above the Sungai Sebangau. The peat deposits here are around four meters deep. The underlying mineral substrate is composed of alluvial clays and sands. This shows complimentary changes in elevation to that of peat on the surface. The peat is particularly acid (usually pH <4.0) because of the prolonged waterlogged/anaerobic conditions.

These elevated peats avoid any riverine or tidal inundation. Therefore the only input of water and nutrients is via aerial precipitation (2000-3560mm per year and the rainy season is October-May). The ombrogenous nature of the peat dome means that the inputs of macro-nutrients are very low. Hence, in most cases, surface water shows little variation from rainwater.

The forest floor is very hummocky with standing water for much of the year in the deepest hollows. There is a notable increase in the number of pneumatophores present from the pole forest to the MPSF as a result of the comparatively high water table.

Compared to lowland dipterocarp forests, there are relatively few species of fern and bryophytes. The forest floor vegetation is comprised mainly of a dense growth of tree saplings of the canopy forest along with sedges. This is because of the sufficient light levels available for sapling growth, hence the resulting exclusion of other forest floor flora. There are several climbers present in this forest as well as epiphytes, insectivorous pitcher plants, rattan and orchids.

The forest is tall, up to 35m, and stratified. An initial estimate of the tree diversity in the mixed peat swamp forest is 100-150 species per hectare, lower than the 240 species found in the coastal peat swamp forest of Sarawak (Anderson, 1964). It contains several commercial tree species, hence the logging disturbance. Below the upper tree canopy, two partially distinct layers form the understorey; a fairly closed layer between 15-25m and a more open layer of smaller trees 7-12m tall.

2.2 Selecting and Marking Transects

In the mixed forest, a series of cut transects already existed adjacent to an old logging extraction railway (Figure 2.2). These transects are used primarily in the observation of orang-utan's and provide easy access to the forest. As other research groups entered the forest via these paths, several manual skid trails were encountered. Aging each of the skids was achieved by comparing the date of discovery and the level of degradation of the skids and related infrastructure i.e. canals (Plate 2.1). The three skid trails chosen were in the age categories:

1. 0-1 years old / transect 2 (Plate 2.2)
2. 1-4 years old / transect 3 (Plate 2.3)
3. >4 years old / transect 4 (Plate 2.4)
4. The control plot created in an area of secondary forest, which had not been logged since the last concession finished in 1996 (Transect 1).

Plate 2.2. Transect 1 (0 - 1 yrs old). This skid was still in working order with obvious damage to the vegetation – notice the tree to the right in the foreground and the relatively large areas of bare soil.

Plate 2.3. Transect 2 (1 – 4 yrs old). This skid was still in a complete state but the amount of vegetation growing in and around it is a good indicator of its redundancy.

Plate 2.4. Transect 4 (>4 yrs old). This skid was in total disrepair, many of the struts were rotten. Much of the skid path was overcome by invading vegetation and tree falls.

Figure 2.2. A satellite map of the natural laboratory used for a logging communications analysis. Setia Alam is marked as the 'Base camp'. The Control transect used in this study was the most northerly one indicated on the map. The disused railways now consist of relatively bare conduits through the forest. There are some remnants of sleepers but the majority was removed as concessions came to an end. The location of illegal logging canals is a good indicator of both the probable locations of skids and the scale of the illegal logging problem in the area.

Once the skids had been selected a transect measuring 100 meters by 20 meters was cut and marked across each. The transects lay at right angles to the skids, with five subplots (10m by 20m) lying either side of the skid (Figure 2.3). The transects were divided into subplots in order to allow for comparisons to be made within transects at a subplot scale. It also made the division of labour more efficient.

The region of each skid investigated was selected where it remained straight enough to intersect the transect more or less linearly between the fifth and sixth subplots. This was to maintain an equal distance between the disturbance and all corresponding subplots, i.e. 1 – 10, 3 – 8 etc.

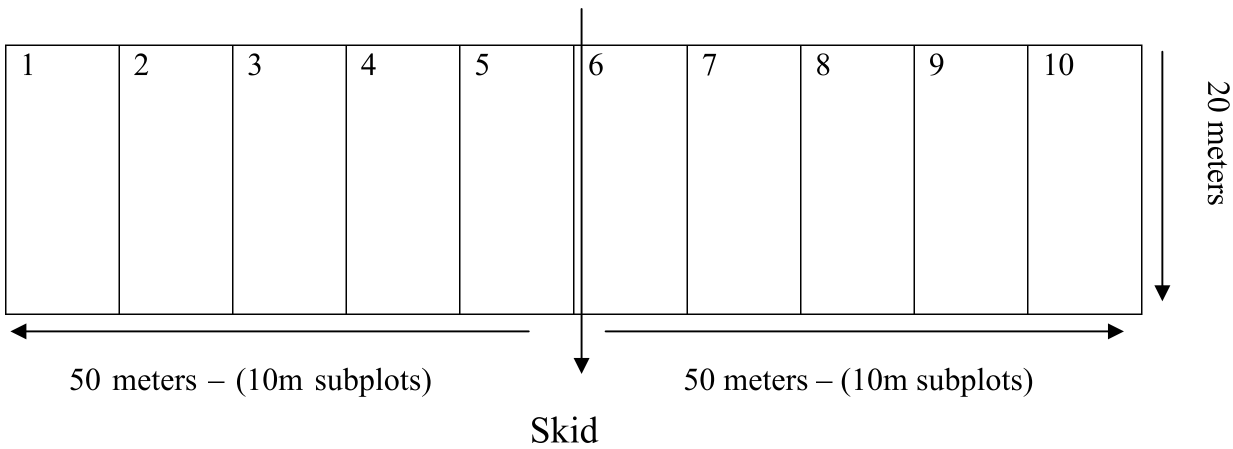


Figure 2.3. Layout of transects

2.3 MEASURING DIAMETER AT BREAST HEIGHT

A dbh tape was used to measure diameter at breast height (1.3 meters from ground level). This tape works on the rule that every 3.1416 inches of circumference is equal to a diameter graduation of one inch.

For several reasons only trees measuring ≥6 dbh were tagged and underwent further observations. Firstly, during the logging concessions 6 dbh was set as the threshold for trees to be extracted as it is commercially viable and allows the smaller trees to maintain a remnant stand. This is a potentially sustainable polycyclic management policy. Secondly, the number of trees measuring ≥6 dbh may act as a good indicator of the scale of illegal logging, because larger trees are once again more desirable, due to greater financial returns. This would emphasise the impact that illegal logging has upon certified management schemes by essentially stealing the next crop of trees. This disruption will encourage the removal of smaller trees in any future concessions. Finally, a minimum size had to be applied due to time restrictions in the field.

2.4 CALCULATING BASAL AREA

The basal circumference was measured at the base of the tree. However, if buttressing was present, the measurement was taken at the top of any buttress. The same applied to the presence of any pneumatophores. This was to avoid any over sizing.

The basal circumference was converted to basal area using the following:

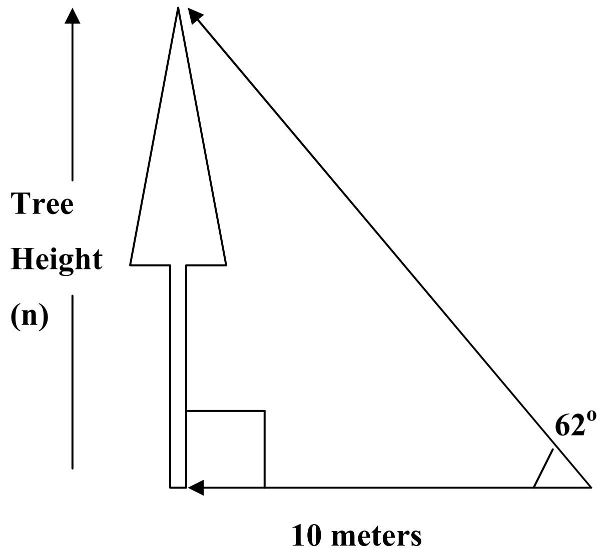
- Diameter = Circumference / π
- Diameter / 2 = Radius
- πr^2 = Area (Basal Area)

The basal area for each subplot was calculated as an indicator of the area within each subplot void of trees. It also reflected the size of trees present, as height is generally positively correlated with basal area (in healthy trees).

2.5 MEASURING TREE HEIGHT

Tree height was measured using a clinometer. Height was measured from a uniform distance of 10 meters (marked with a tape), unless sight of the tree top was impeded. Any changes of distance to the tree were noted and the calculation was later adjusted.

Height was then calculated using simple trigonometry e.g.:



Tan 62 = n/10

Keyed as: 10 × 62 tan = n
(plus the height of the clinometer operator).

This method of measuring height does have some discrepancies as results may vary with fluctuations in the ground surface. However, deviations were rarely greater than 0.5 meters.

2.6 CANOPY COVER AND SOIL COMPACTION

The canopy cover and soil compaction were measured at five locations within each subplot (Figure 2.4) in order to produce an average for each variable.

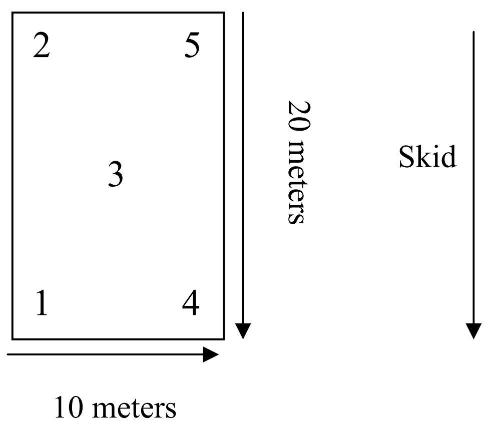


Figure 2.4. Positions of canopy cover and soil compaction measurements within each subplot.

Canopy cover was estimated at four different heights at each point in the subplots. This was done by looking through a segmented, funnel eyepiece and estimating the percentage cover. The heights measured were 0-2m, 2-5m, 5-10m and 10+m. Height was measured using pre-marked canes. An average was taken for canopy cover at each of the four levels. This method is somewhat subjective, but was adequate in identifying general trends in canopy height distribution and canopy gaps.

Soil compaction was measured using a tubular penetrometer, which was simply pushed into the soil giving a reading for soil compaction. Again this produces less than precise results but adequately identifies any major trends that may occur.

Due to the nature of the apparatus used to measure these variables, a single person took all canopy and soil measurements to minimise variation/error.

2.7 SAPLINGS PLOTS

A single two-meter squared sapling plot was set up in each of the subplots. Their location was chosen using random numbers (between 1-50 in each subplot, 10×20 meters) to avoid bias selection.

Once selected the plots were marked out, and the heights of all saplings were then recorded. None of the shrubs and other under storey plants was measured, as it was an observation of tree regeneration alone. A qualified botanist from the University of Palankaraya, Kalimantan, verified species identification.

2.8 PLOTTING THE X-Y CO-ORDINATES

All tagged trees had their X-Y co-ordinates recorded. Co-ordinates were taken by placing a tape measure down each axis of the subplots, then reading off the tree position in relation to both. The 10m side of the subplots was taken as the X-axis and the 20m side as the Y-axis.

Measuring the co-ordinates of all trees included in the study ensured that transects had been marked accurately and that no crossing over or replication of data occurred between subplots.

2.9 REPLICATION

Both of the factors being investigated included some replication. Each age category was essentially replicated either side of a skid, giving two replicates. The distance factor under went hidden replication, with two replicates at each transect giving a total of eight replications.

2.10 ANALYSIS OF VARIANCE (ANOVA)

All data collected in the field was analysed using ANOVA with the 'Genstat 6th Edition' package. The original data set would not run in this package, as it was unbalanced. This was due to the lack of blocking and the uncontrolled natural laboratory i.e. each sub-plot contained different numbers of trees. In order to balance the data set a mean was taken for each variable and then run through the ANOVA.

The ANOVA was set as 'completely randomised' as the practical design did not incorporate any blocking. The analysis was run to look for all interactions. This meant that any statistically significant trends within and between the two factors being investigated, skid age and distance from skid would be picked up.

Chapter 3: RESULTS

3.1 RESULTS

Only variables that exhibited statistically significant variations in the ANOVA have been plotted in the results. The complete data set has been presented in the appendix.

The transects have been referred to by age in figures 3.1 – 3.10, so that data could be presented in chronological order, i.e. transect 1 = >6yrs, transect 2 = <1 yr, transect 3 = 1-4 yrs and transect 4 = >4 yrs.

3.2 NUMBER OF TREES

There were no significant differences found between or within transects for the number of trees present (> 6 dbh).

3.3 BASAL AREA

Basal area between and within transects showed no significant differences in the ANOVA.

3.4 TREE HEIGHT

The control plot, transect 1, had a statistically significant greater average tree height than any of the other transects as expected. However, no significant difference was observed between the different skid age categories. This is contrary to what was expected (Fig. 3.1).

There were no statistically significant differences observed for changes in mean height with distance from the skid.

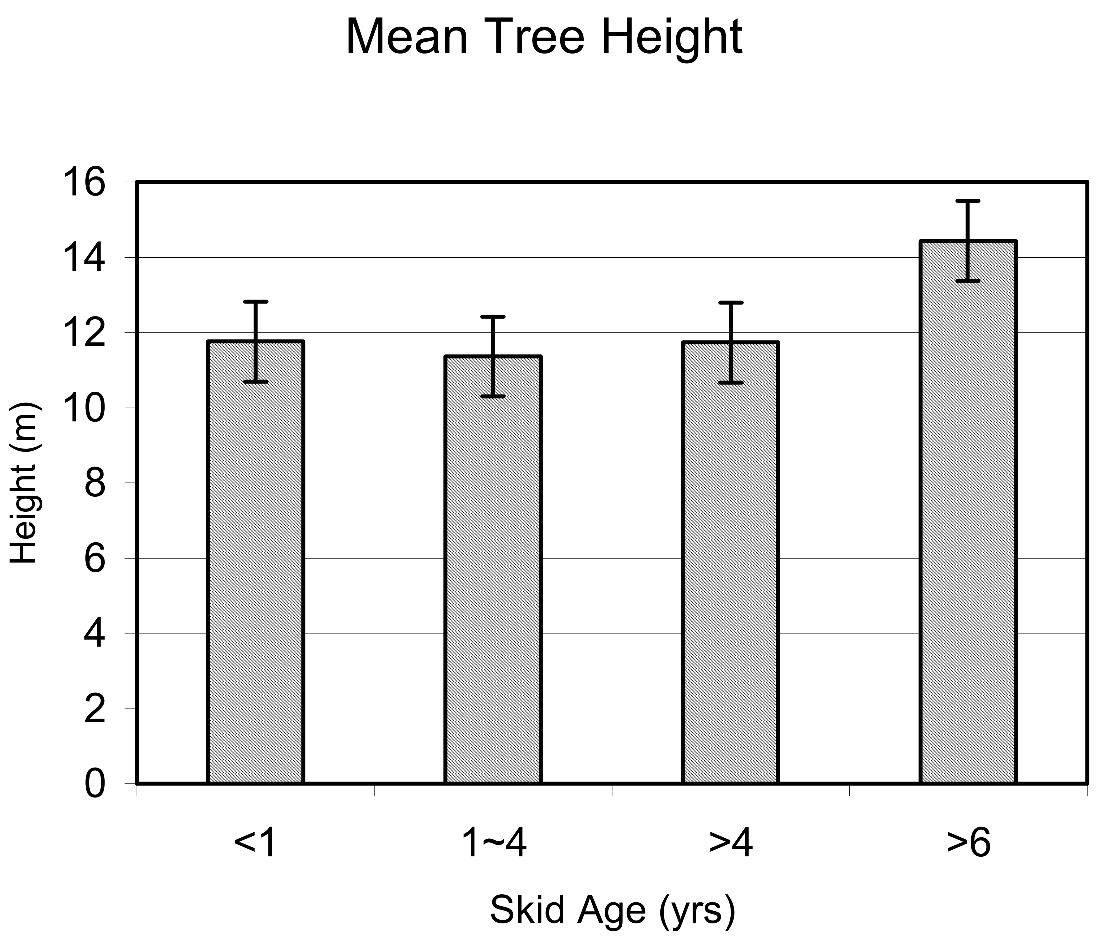


Figure 3.1. The effect of skid age upon tree height. Error bars show SED = 1.063, 20d.f. (F – pr = 0.033). Statistically significant differences between transects: 1 > 2 & 3 & 4.

3.5 CANOPY COVER

3.5.1 Canopy Cover 0 – 2 metres

As expected, transect 4 has a higher percentage canopy cover at 0-2 metres (Fig. 3.2) than transect 1.

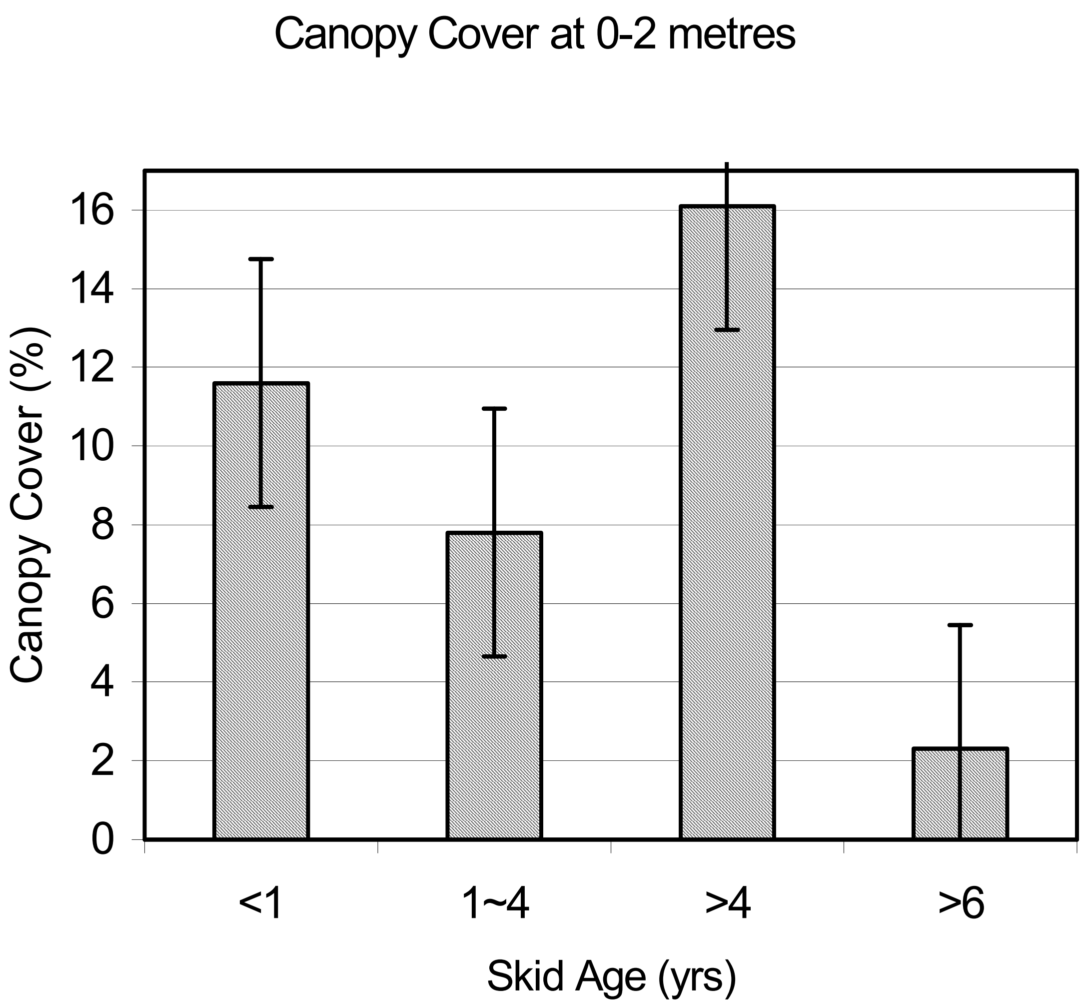


Figure 3.2. The effect of skid age upon percentage canopy cover at 0 – 2 metres. Error bar shows SED = 3.15, 20 d.f. (F-pr = 0.002). Statistically significant differences between transects: 2 > 1, 4 > 1 & 3.

3.5.2 Canopy Cover 2 – 5 metres

At 2-5 metres (Fig. 3.3), transects 2 and 4 had a significantly greater percentage canopy cover than transect 3. This does not follow the expected trend.

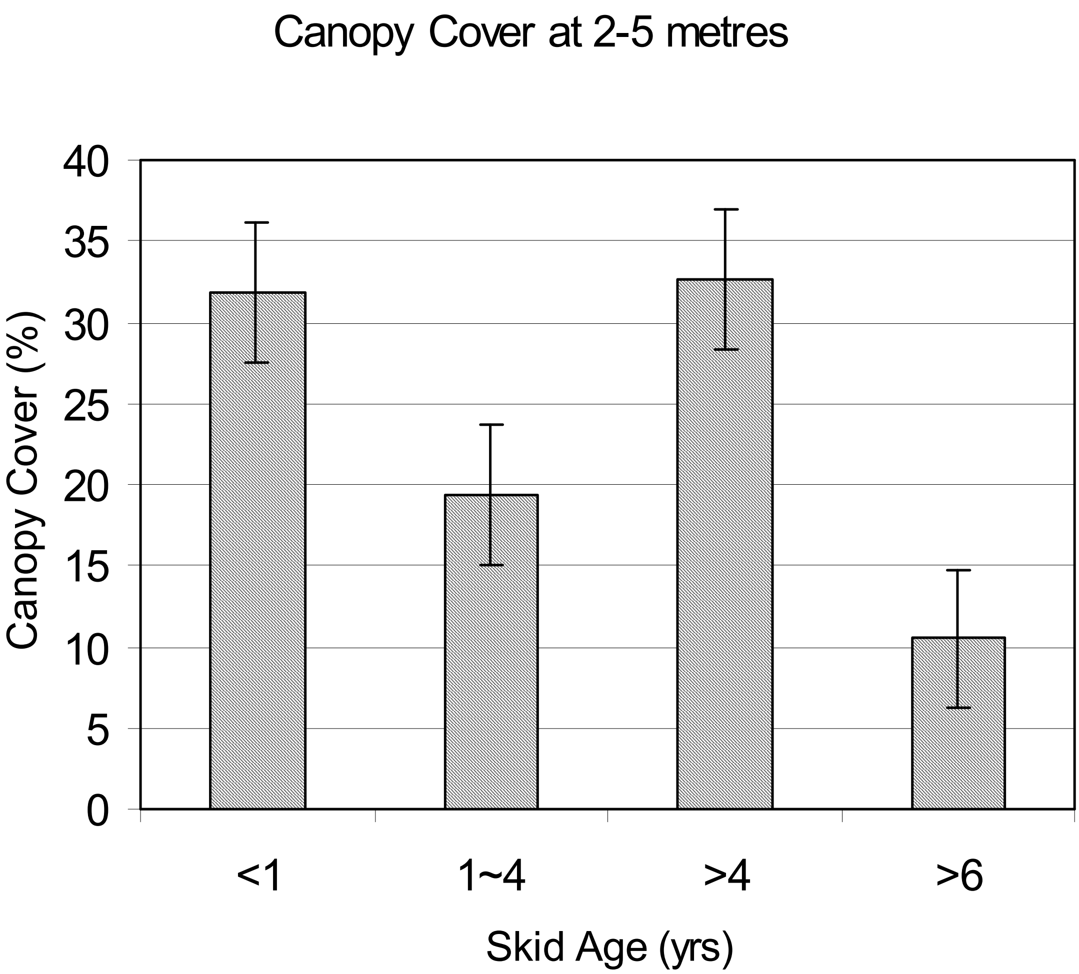


Figure 3.3. Effect of skid age upon percentage canopy cover at 2 – 5 metres. Error bars show SED = 4.3, 20 d.f. (F-pr = <.001). Statistically significant differences between transects: 2 & 4 > 1 & 3, 3 > 1.

3.5.3 Canopy Cover 5 –10 metres

Transect 3 consistently breaks the expected trend and appears to be an anomaly. At 0-2, 2-5 and 5-10 metres (Fig. 3.4), it is lower than was expected and it is higher than expected at 10+ metres.

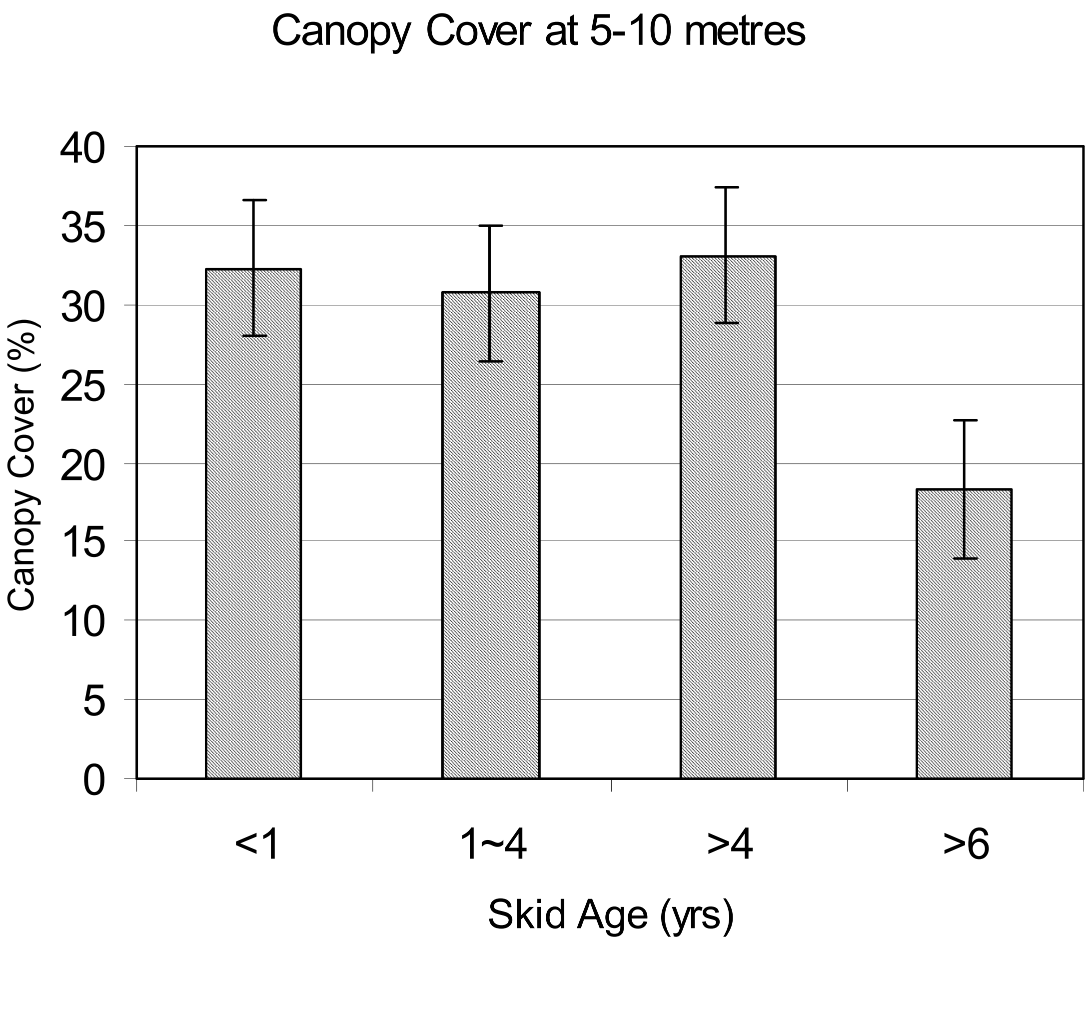


Figure 3.4. Effect of skid age upon percentage canopy cover at 5 – 10 metres. Error bars show SED = 4.3, 20 d.f. (F-pr = 0.008). Statistically significant differences between transects: 2 & 3 & 4 > 1.

3.5.4 Canopy Cover 10+ metres

Percentage canopy cover was greater at all heights in transects 2-4 than in the control, transect 1, except for 10+ metres (Fig. 3.5).

No statistically significant differences in percentage canopy cover were observed with increasing distance from the skid.

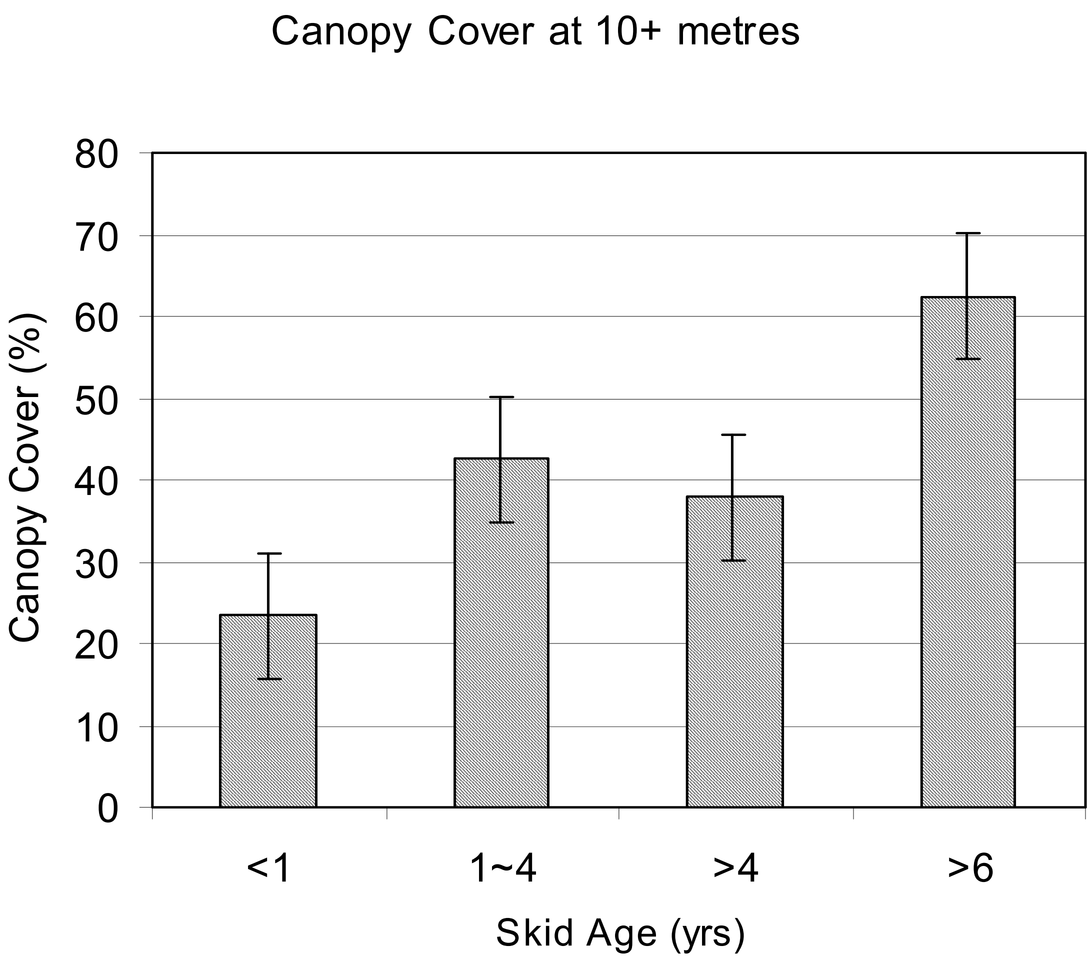


Figure 3.5. Effect of skid age upon percentage canopy cover at 10+ metres. Error bars show SED = 7.64, 20 d.f. (F-pr = <.001). Statistically significant differences between transects: 1 > 2 & 3 & 4, 3 > 2.

3.6 SOIL COMPACTION

3.6.1 Skid Age

Soil compaction at transects 4, 3 and 1 was significantly greater than at transect 2 (Fig. 3.6).

The most recently disturbed site (transect 2) was, in fact, expected to have the greatest soil compaction. No other significant differences were observed

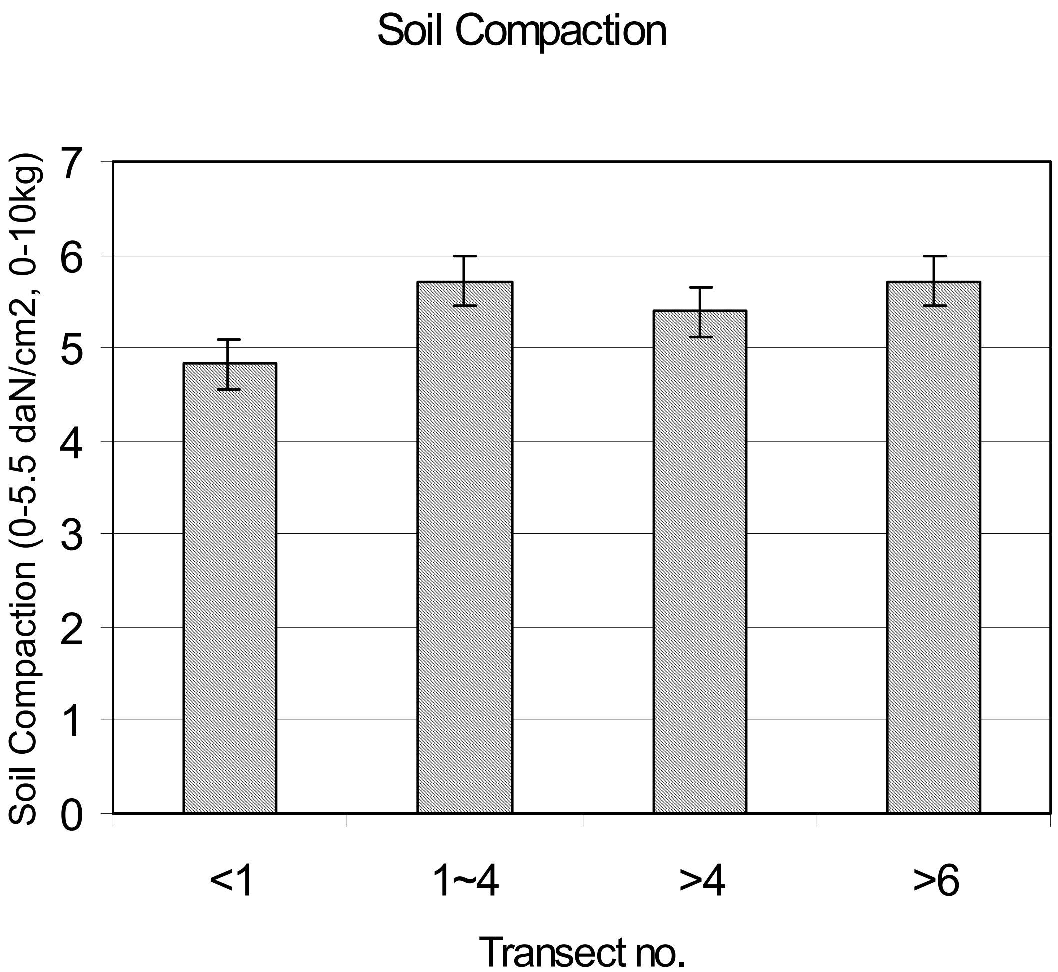


Figure 3.6. The effect of skid age upon soil compaction. Error bars show SED = 0.2659, 20 d.f. (F-pr = 0.01). Statistically significant differences between transects: 4 & 3 & 1 > 2.

3.6.2 Distance from Skid

Differences in soil compaction with distance from the skid were also significant (Fig. 3.7). The soil compaction was significantly greater at 5 metres than at 15, 25 and 35 metres as expected. However, for some unforeseen reason soil compaction was significantly greater at 45 metres than at 25 metres. The general trend is as expected from 5–35 metres but the incline on the graph at 45 metres does not fit with the expected effect of distance from disturbance

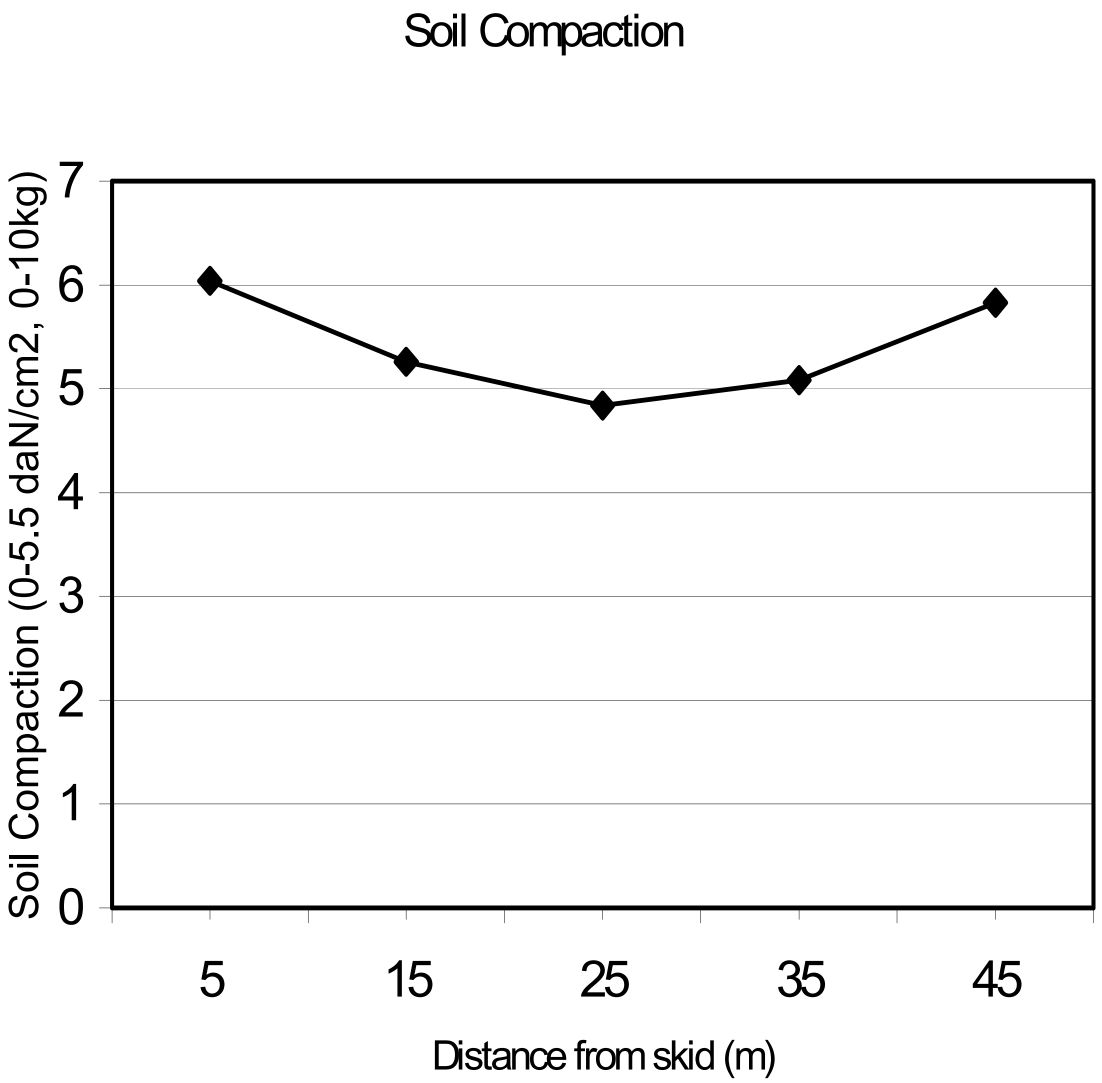


Figure 3.7. The effect of distance form skid upon soil compaction. Error bars show SED = 0.2973, 20 d.f. (F-pr = 0.003). Statistically significant differences between transects: 5 > 15 & 25 & 35, 45 > 25.

3.7 CANOPY DIAMETER

As was expected, the mean canopy diameter (Fig. 3.8) was significantly greater in transect 1 than 2, 3 or 4. This is consistent with its greater tree height and percentage canopy cover at 10+ metres (larger trees). Transects 3 and 4 had significantly greater mean canopy diameters than transect 2.

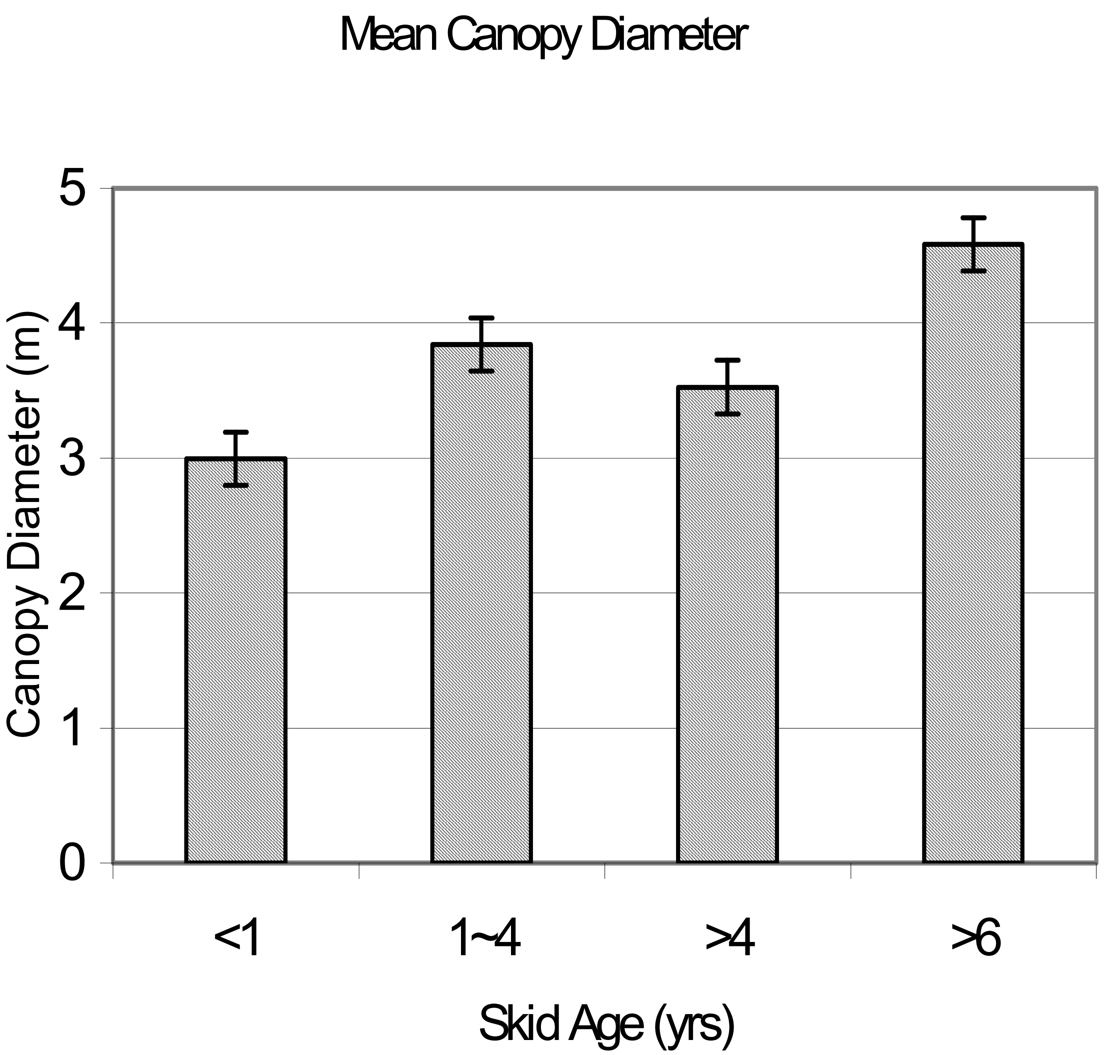


Figure 3.8. The effect of skid age upon canopy diameter. Error bars SED = 0.1974, 20 d.f. (F-pr = <.001). Statistical significant differences between transects: 1 > 2 & 3 & 4, 3 & 4 > 2.

3.8 SAPLINGS

3.8.1 Age of Skid

Transects 1 and 3 had significantly greater numbers of saplings than either transects 2 and 4 (Fig. 3.9).

It is not surprising that transect 3 has significantly more saplings than transect 4. It is not clear why transect 3 has significantly more and transect 4 has more saplings than transect 2.

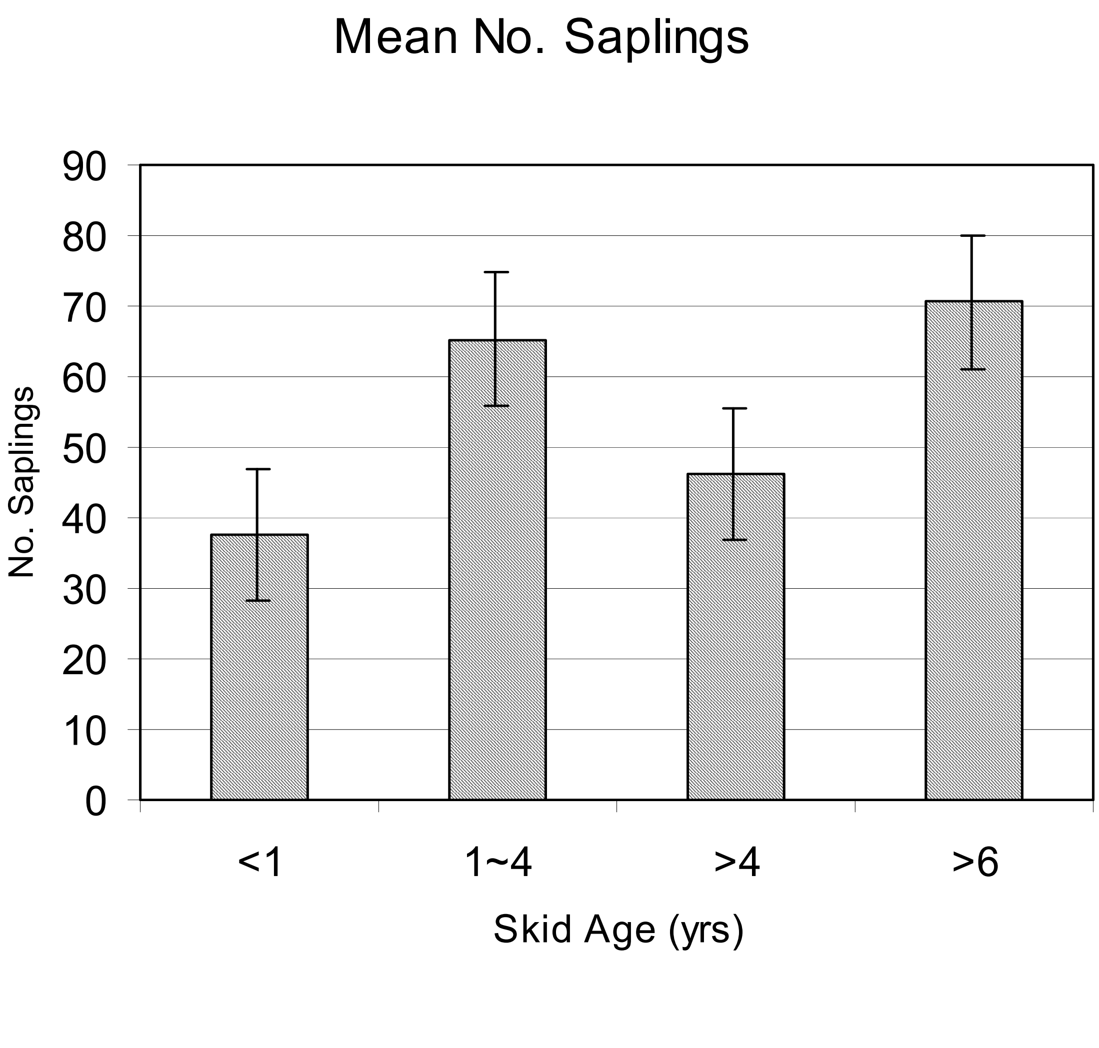


Figure 3.9. The effect of skid age upon the number of saplings. Error bars show SED = 9.46, 20 d.f. (F-pr = 0.007). Statistically significant differences between transects: 1 & 3 > 2 & 4.

3.8.2 Distance from Skid

Distance from the skid was also shown to influence the number of saplings present (Fig. 3.10). At 5 and 25 metres there were significantly more saplings than at 15, 35 or 45 metres.

The general trend shown in Figure 3.10 is that the number of saplings is negatively correlated to increased distance from the skid disturbance. This is why the value at 25 metres was unexpected.

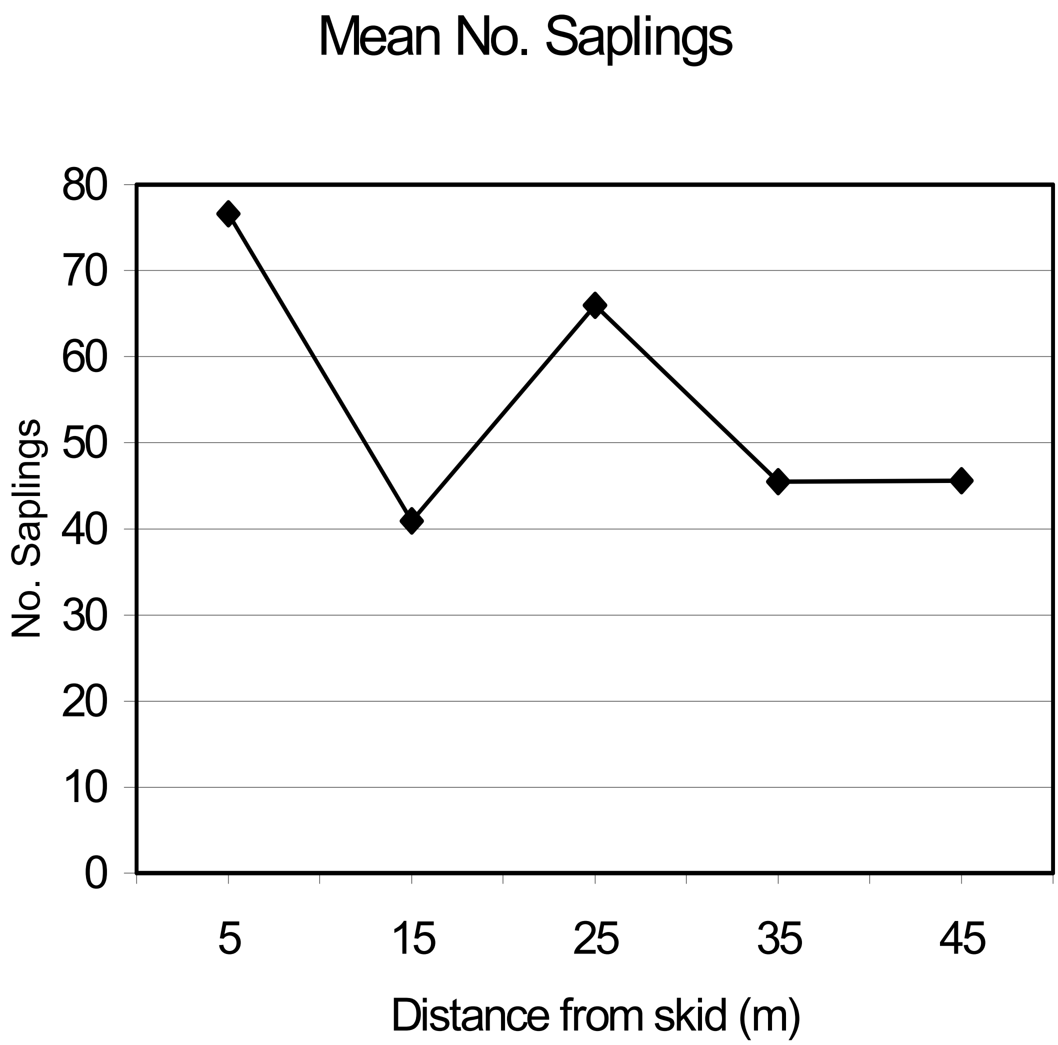


Figure 3.10. The effect of distance form skid upon the number of saplings. Error bars show SED = 10.58, 20 d.f. (F-pr = 0.011). Statistically significant differences between transects: 5 & 25 > 15 & 35 & 45.

Chapter 4: DISCUSSION

4.1 THE EFFECT OF MANUAL SKIDDING UPON VEGETATION

4.1.1 Tree Height

Transect 1 (>6 years fallow) probably has the greatest mean tree height (Figure 3.1) as it has been left fallow since the end of the last logging concession in the Sungai Sebangau catchment. Therefore, the vegetation within this transect appears to have had a significantly longer period of time for succession and regeneration. This difference may also have been accentuated by the absence of illegal logging practices within the control. Illegal logging practices are notoriously less sympathetic to the next generation/crop of trees, i.e. no minimum dbh is enforced.

Significant differences were expected between transects 2-3 for similar reasons. As time after skid disturbance increases, tree height was predicted to increase. No such trend was observed. This may be due to the illegal logging practices employed within these transects or secondary factors related to the presence of a skid trail. This may include a modified micro-climate, i.e. temperature. The soils of a semi-deciduous forest in Ghana showed variations in temperature between enclosed forest and exposed soils (Mabberley, 1992). Increased human influence along the artificial conduits may also play a role.

The most obvious reason for reduced mean tree height around more recently constructed skid trails is that the largest trees are the first to be removed and the remnant stand has the least amount of time to mature. However, the lack of a significant difference between any of the other age categories suggests that the difference may be due to factors other than skid age. Again, this suggests that it may be a result of illegal logging practices.

4.1.2 Soil Compaction

Soil compaction was significantly affected by distance from skid (Figure 3.7). The general trend was as expected, with a increasing level of soil compaction with proximity to the skid disturbance. This is based upon the assumption that disturbance decreases with distance from the skid. Soils adjacent to the skid will undergo prolonged trampling and compaction during skid construction and operation. Whereas, soils further afield will only be disturbed as timber is felled and removed. It is also fair to assume that a single skid has a restricted sphere of influence, as it would not be economical to fell trees to far from a skid. However, this is not without exception, as soil compaction was greater at 45 metres than at 25 metres. It is possible that this was due too felling at 45 metres, experimental discrepancies or external factors such as increased elevation.

Transect 2 has a significantly lower level of soil compaction (Figure 3.6) than any of the other transects. This is not consistent with past studies, as soil compaction is generally associated with disturbance. Two studies of Kalimantan by Abdulhadi *et al.* (1981) found that soils under logging communications were subjected to compaction and surface blading. This resulted in decreased infiltration rates. Despite this no other significant differences were observed between transects.

New logging plans are incorporating soil rehabilitation programs in order to ameliorate the negative impacts of soil compaction (Dykstra & Curran, 2000). Negative effects (Figure 1.1) include reduced water infiltration, soil moisture availability, aeration and rooting space (Graecen and Sands, 1980). These are unfavourable growing conditions for the majority of flora and may result in reduced uptake of water and nutrients. This often results in wilting, premature senescence or in extreme circumstance's necrosis.

Jackson *et al.* (2001) stated that there is significantly less damage sustained along skid trails than along logging roads. This is probably due to the increased mechanisation along more established logging roads. Despite this, it is obvious that soil compaction caused by manual skidding is a problem.

Water deficiencies in the MPSF may have been further exasperated by the construction of logging canals (Plate 1.3), which have progressively depleted the peatland of water, ultimately lowering the water table and water availability. A shortage of water is directly associated with nutrient uptake through the soil plant atmosphere continuum (SPAC) as nutrients are carried in solution.

4.1.3 Canopy Cover and Canopy Diameter

The jettisoning of leaves, because of deficiencies may have contributed to the differences observed in canopy cover. However the main reasons for such differences are probably associated with the tree height and canopy cover. Webb (1997) found that post-logging canopy cover was negatively correlated to the number of trees extracted.

The nutrient requirements of a mature tree are greater than that of a sapling. Therefore, a nutrient deficit is more likely to have negative consequences upon larger trees. One of the most apparent physiological signs is smaller plants, as root to shoot ratios rise and overall nutrient partitioning becomes less optimal.

With the loss of vegetative cover through abscission and reduced plant size due to nutrient deficiencies, the percentage canopy cover and canopy diameter (Figure 3.8) would consequently be reduced in more recently disturbed transects.

Johns *et al*, (1996) observed a 20-40% reduction in canopy cover and tree density. This is not consistent with this study, as canopy cover was consistently out of trend in transect 4 (Figure 3.3, Figure 3.4) except at 10+ metres. This may have been due to untested factors or differences in logging intensity/practice. Furthermore, no significant differences were observed in tree density. It is accepted that tree height in all secondary canopies matures at a lesser height than that of the ancient primary forest. This is due to changes of environment and species composition.

Transect 4 had a significantly greater percentage canopy cover at 0-2 metres (Figure 3.2) than transects 1 and 3. This was not expected as disturbance was more recent in transects 2 and 3. Disturbance is associated with increased light intensity in the under storeys and hence an abundance of ground flora, dominated by fast growing herbaceous pioneer species. Therefore, it was expected for the lower canopy density to be greater in the most recently disturbed transects and least in the older skid transects.

The intermediary strata in the canopy at 2-5 metres and 5-10 metres were expected to grade from the high percentage cover at 10+ metres for transect 1 (>6 years) through to the greatest canopy cover observed at 0-2 metres, in transect 2 (<1 year). The precedence for this argument is the phenomenon of secondary forest succession.

With the removal of a primary stand, whether it is through a natural or anthropological event, secondary vegetation begins to flourish. This is initially in the form of pioneer species, i.e. lianas. An area of forest at Kapong, Malaysia, isolated from forest seed bearers was initially colonised by 21 woody species. This was gradually overcome with ferns. This, temporarily, prevented the establishment of more woody species. After a further 14 years the canopy was again dominated by the initial colonisers, with large dipterocarps becoming established after 32 years (Kochommen, 1977). The secondary forest canopy is comprised of trees from both the typical primary stand and the secondary stand (pioneer and shade intolerant species).

At 2-5 metres (Figure 3.3) the effect of pioneer vegetation was still prevalent, with the greatest canopy cover in transect 2. However, at 5-10 metres (Figure 3.4) the expected transition to an elevated canopy did not occur. The effect of disturbance still seemed to be the controlling factor in canopy/strata distribution.

The greater percentage canopy cover at 10+ metres (Figure 3.5) in transect 1 can be related to its greater mean tree height (Figure 3.1) and canopy diameter (Figure 3.8). This is probably because more of the commercially desirable, emergent species, still remain in the control transect as it was logged in a concession, and hence was relatively more sustainably managed.

4.1.4 Saplings

The positive trend observed between skid age and number of saplings (Figure 3.9) does not follow the above explanation of secondary succession. The greatest number of saplings was recorded in transect 1, where canopy cover at 10+ metres and canopy diameter was greatest. This suggests a high level of shading, which is not indicative of high numbers of saplings.

High numbers of seedlings are generally associated with some form of disturbance to the upper canopy layers, as this increases light, water and nutrient availability and rooting space. Many seeds endure some period of dormancy. This may be under photocontrol or thermal control (Vasquez-Yanes & Smith, 1982). Both of these mechanisms require prolonged exposure in order to trigger irreversible germination. Therefore, any mediated level of stimulus will not suffice, i.e. sunflecks may not provide enough light to reduce the red:far red ratio, or heat. Some seeds may only germinate if they are heated to 40^{0C}.

The lack of consistency between this study and past studies may be because conditions for tree growth are sub-optimal, post logging disturbance, until stabilised by incoming pioneer vegetation, such as ferns and sedges. Alternatively, differences may have come about due to differences in data collection.

The trend of sapling density with distance (Figure 3.10) was similar to that of soil compaction. This is unusual, as the effects of compaction upon tree growth are far from ideal (see above). It is no surprise that sapling density was greatest closer to skid disturbance, despite the incidence of compaction. At 5 metres there is likely to be a higher incidence of light and heat. Sapling establishment adjacent to the skid trail may also be promoted by the redistribution of seeds and organic matter (Croke *et al*., 1999).

4.2 SECONDARY FOREST REGENERATION

A frailty of a dependence upon seed banks for regeneration is that they tend to contain seeds from species that are absent or rare in the vegetation growing above them. This is because they are poor competitors, generally pioneer species. In this case any secondary forest may be unstable and less complex. The tall pole forest of the Sebangau catchment was completely devastated by fire. Just two years later the whole area was blanketed in ferns. This post fire abundance of lianas or ferns may blanket a stand reducing the tree productivity through shading.

Alternatively the protracted dormancy employed by many seed species common in seed banks could be viewed as a successful strategy for the colonisation of habitats undergoing an increasing frequency of disturbance.

4.3 ALTERNATIVE USES

Forests can support large communities with food and livelihoods. Dove (1983) noted the importance of income from rubber and rattan to shifting cultivators in Kalimantan.

NTFP's contribute greatly to the incomes of populations living in and adjacent to forests. This form of exploitation is a lot less destructive than removing timber, and is a far more sustainable function of the forest, retaining large amounts of plant and animal biodiversity (Michon and de Foresta, 1997). If NTFP's can be managed at a commercial level it may increase the perceived value of remaining forests and therefore increase the incentives for conservation. Peters (1994) suggested that the potential income from such products could be considerably higher than timber income. This has led to the 'conservation by commercialisation' hypothesis (Evans, 1993). This is a potentially dangerous idea, due to the political circumstances discussed earlier.

Another problem is the difference in tolerance between species. This may lead to a loss of diversity, if the people utilising such products are not supervised. The over hunting of important predators and seed dispersers will influence the composition and structure of forests. Homma (1992) argues that as a commercial demand for a forest product emerges, the output initially grows then the quantity and quality will fall, pushing prices up. The inelasticities of the natural supply then promote the development of domesticated and synthetic alternatives. This is based upon evidence from the Amazon rain forest. The people that benefit from such management are generally the poorer classes, who contribute less to the economy. Therefore, it is likely that local legislation is going to favour the wealthier timber merchants who will pay more money.

The use of NTFP's is not a new idea, the forests of the world have been actively managed for a range of products for many years. Damar, rattan and fruits are actively managed in the forests of Indonesia. This process is under threat due to government policies asserting state control over the forest resource and undermining the authority and management of sustainable community level institutions. This has a number of negative effects. It creates a lack of respect for the resource due to the 'tragedy of the commons' phenomenon. Large-scale exploitation may move in as a bid for accelerated development. This was illustrated very clearly in the northern states of India and resulted with the formation of local opposition 'Chipko'. Similar movements emerged in S. America, i.e. 'The rubber tappers'. Therefore it can be concluded that conservation interests in NTFP's and those of development do not coincide.

Many indigenous groups have been lost from the amazon (Alcorn, 1993), and a number of Dayak groups have been overrun by logging in Sarawak. As the indigenous populations become less dependent upon the forests due to trade and other external influences, there will be a loss of important knowledge, which is a real threat to the long-term status of the remaining forests.

4.4 CONSERVATIVE STEPS

Avoided deforestation is always more beneficial to the environment than tree plantations (Fearnside, 2001). Desirable species such as the mahoganies (*Khaya* and *Entandrophragma*) were replanted in logged areas during the 1940's and 1950's to encourage their re-establishment, herbicides were even applied to the less desirable species. However, research has since shown that natural regeneration is just as successful (Figure 4.1).

International concern has led to the production of a number of conservation directives and conventions for such land areas:

- The Convention on Biodiversity (CBD)
- The UN Framework Convention on Climate Change (UNFCCC) regional initiatives such as the ASEAN Regional Action Plan on Transboundary Haze.

A ‘Global Action Plan for Peatlands’ (GAPP) is currently being prepared on behalf of the Ramsar Convention for distribution to all contracting governments, including Indonesia.

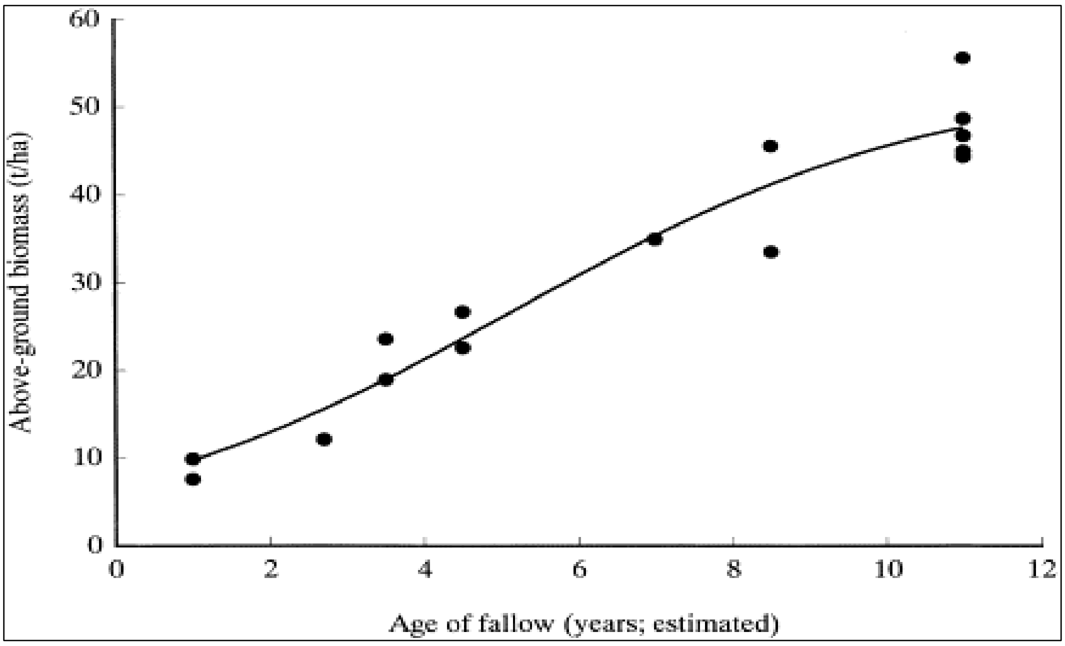


Figure 4.1. Relationship between age of fallow and above ground biomass (Eastern Kalimantan). The line denotes regression by logistic curve. (Source: Hashimotio et al. 2000).

It is often difficult to drum up international support for ecological sectors. The process is made easier if a familiar and popular face can be put on the area. The Sebangau catchment is home to the largest single population of orang-utans in the world, with an estimated population of >6000 in the western Sebangau catchment alone (Morrogh-Bernard, 2002). There is currently no protective status covering this population which is suffering due to the extreme levels of illegal logging, and general human interference which are thought to reduce fecundity and reduce range size (MacKinnon, 1990). This may help in the future conservation of the peat swamp forests.

4.5 FURTHER WORK

Over the past 100 years huge quantities of data have been collected regarding the tropical peatlands of the world, and less specifically, rain forests. The data collected for this study was gathered over just six weeks. In order to create an accurate portrayal of the current situation within the Sungai Sebangau catchment, more time must be spent in the field. This would permit the use of less speculative recording apparatus.

The variables investigated in this study were characteristics influenced by more specific factors. In order to improve the value of this data a number of other variables should be recorded, so that the causes of the variations highlighted by this project may be isolated:

- Hydrology – the height of the water table throughout transects may have fluctuated as well as its chemistry, i.e. diesel from chainsaws etc.
- Soil properties – the bulk density and nutrient content may have influenced factors such as sapling density.
- Temperature – the variation in temperature between canopies, subplots and transects is important. This may determine the scale of germination or water status.
- Wind speed – again this may have varied between transects as vegetation composition differed. Wind influences the local humidity and litter distribution.
- Light intensity – a scale of shading would be very constructive, as this is a key component in determining stand composition.
- Litter composition and distribution – this is important in determining both the distribution and type of vegetation.

The transects cut and marked for this study are under continuing observation. This study is to be repeated annually, in order to create a record of regeneration and the chronic impacts of manual skidding.

Maintenance of any ongoing study site in the natural laboratory is very difficult because of a lack of tolerance from the illegal loggers.

Chapter 5: SUMMARY AND CONCLUSIONS

The results of this study suggest that manual skidding has a negative impact upon the MPSF of the Sungai Sebangau catchment. This is especially alarming when Hendrisons (1990) study is taken into account. He indicated that 10% of the land area in Indonesia is deforested for the construction of skid trails. When the impacts of the complete logging communication networks are included the negative impacts are magnified, e.g. canals and landing sites.

Both distance from skid and age of skid had an influence upon vegetation. Age of skid was statistically more influential upon the vegetation within the 100 × 20 metre transects, than distance from the skid disturbance.

Transect 1 consistently exhibited trends characteristic of a natural forest. This suggests it was differences between techniques employed in illegal logging and those used during the concessions that caused the variations observed. This may provide some help in the development of future RIL techniques. Johnsa *et al.* (1999) showed that profit margins could in fact be greater with the operation of RIL techniques.

The general trends observed with age of skid indicate that regeneration (Figure 4.1) and a return to natural state does occur. This is consistent with past investigations, i.e. Plumtre (1996) suggested that a period of fifty years is required for a forest to return to a pre-logging condition. It has also been proposed that changes in soil properties caused by logging may recover decades after (Van der Plas & Bruijnzeel, 1993) as compaction is alleviated through rooting and invertebrate action.

Therefore, logging on a realistic polycyclic scale may be sustainable. In order to implement this, illegal logging would have to be policed effectively. The export of timber from Indonesia was banned in 1985, but illegal logging is still rampant across the forests of Indonesia.

Alternative sources of income may be derived from the forest during periods of regrowth in the form of NTFP's. Extreme measures to save the remaining peatland forests include the reversion from natural forest logging to mass plantation schemes, as suggested by Davies (1989).

There is a huge amount of literature justifying the appeals to incorporate this area into a national park. Action must be taken immediately if the peatland forests of Central Kalimantan are to be conserved.

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