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ABSTRACT

Managing the forested landscape in Malaysia and Indonesia for timber extraction while also conserving the endangered orangutan that inhabit some of the remaining forests in this region is a challenge. Heavy logging is a common feature of the Indonesian and Malaysian timber industries. It is profitable but detrimental to the survival of this primate species. A type of logging which appears to be compatible with maintaining orangutans in the forested landscape is light logging. It involves extracting fewer logs and ensures that the logged area is minimally damaged. However, switching to a light logging regime involves a financial opportunity cost, a cost which is an obstacle to the widespread adoption of this type of logging by businesses and the state. This paper reviews the case study of a unique light logging experiment conducted in the Deramakot Forest Reserve, in one of the orangutan's strongholds, the Malaysian state of Sabah. The Deramakot experiment claims to generate revenue from low-impact logging while also sustaining its population of orangutans. Here, we survey the importance of the timber industry to Sabah, the profitability of the Deramakot scheme, the orangutan conservation aspect of this scheme, and the influence of the politico-bureaucratic factor or public economicson sustaining the domestic light-logging agenda. Then, this paper attempts to answer the question of whether economic returns could be balanced with orangutan conservation given the light and heavy logging regimes, bearing in mind the opportunity costs associated with these. More specifically, using the data that has been made available from the Deramakot case study, this paperemploys a mathematical model to analyse whether the foregone profits of pursuing light logging is higher than setting aside strict protected areas while more intense logging the remaining forests, subject to the goal of maintaining a desired orangutan population size. The results reveal that, under certain conditions, the option of conserving the orangutan under mainly light logging is economically more attractive for a scenario involving Sabahan forests than the option of strictly protecting orangutan habitats and heavily logging the forests without significant orangutan populations. This finding contributes to the question asked by conservationists of how forests should be partitioned to satisfy both economic and conservation needs.

JEL Classifications: H00, Q23, Q57

Keywords: Biodiversity conservation, government, orangutan (*Pongo pygmaeus* spp.), opportunity cost, sustainable logging, timber.

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1. Introduction

The production of palm oil in Malaysia and Indonesia has involved the conversion of vast areas of tropical forests in these countries into oil-palm cropland (Lee et al., 2014, pp. 25-26). This agricultural land-use change has impacted the region's biodiversity (Fitzherbert et al., 2008). A prominent wildlife species that is being threatened by this process is the orangutan (*Pongo pygmaeus* spp.), Asia's only great ape species, which is reliant on natural-forest cover for its long-term survival. However, the other major factor causing the decline of the orangutan's natural habitat is intensive timber extraction. This matter has received less attention with the rise of the oil-palm threat, but is important to address: it has been argued that more orangutans occur in natural forests that are exploited for timber than in areas targeted for other land uses (Ancrenaz et al., 2010, p. 1; Wich et al., 2012, p. 7).

While heavy logging is detrimental to this primate, evidence seems to indicate that low-impact and sustainably logged forests can accommodate the survival of orangutans *in situ*. In other words, the extraction of commercially-valuable timber from tropical forests for revenue is possible without being entirely antagonistic to the survival of orangutan populations, at least in the short- to medium-term (Ancrenaz et al., 2010; Knop et al., 2004; Marshall et al., 2006). This occurs if suitable forest structure and food plants (e.g., figs and lianas) are retained following logging (Ancrenaz et al., 2010, p. 7; Hardus et al., 2012; Knop, et al., 2004), something not possible under plantation agriculture.[1] To an extent, therefore, logging is seen as a promising

[1] Agroforestry in cash crop production, such as for oil palm, has been considered for retaining biodiversity in an agricultural matrix (Bhagwat and Willis, 2009) but it is unlikely to be adopted at scales approaching that of standard monoculture production due to the costs involved in changing established practices, reductions in profits per unit area, and intrusion into and disturbances to production from wildlife such as orangutans. But keeping forests for natural timber production protects against outright forest losses. In one Bornean timber concession, forest loss was reported to be below 0.1% per year compared to the Kalimantan average of 2.0%, implying that well-managed timber concessions can protect biodiversity better than some poorly-enforced protected areas (Meijaard and Sheil, 2007).

economic–conservation compromise as far as the orangutan is concerned. Adjusting logging intensity, i.e., the number of trees harvested per unit area, between what can be regarded as light or moderate and the more conventional type of intensive logging, extending the duration of logging rotations to facilitate forest regeneration, and selecting where logging is to be carried out where the orangutan is distributed, are key variables, and alters the numbers and densities of orangutans and therefore the probabilities of their survival. Field studies suggest that it may be possible to select timber harvesting levels that corresponds to reasonably safe margins for maintaining orangutan populations in an area.

Orangutan density data in relation to experimental, reduced-impact logging (RIL) carried out at the Deramakot Forest Reserve in the Malaysian state of Sabah, where a sizeable orangutan population is found, seems to attest to this (Mannan et al., 2003; Lagan et al., 2007; Mannan et al., 2008). This project is directly managed by the Sabah government (Ong et al., 2013, p. 2) and is carried out as part of Sabah's plan to extend sustainable forest management (SFM) to its entire timber production forests. SFM is "an integrated management concept that aims at making a profit from timber production while maintaining environmental and social services", and involves "(1) allocating an adequate area for conservation, (2) calculating annual allowable cutting (AAC) based on data of standing stock and prediction of growth of harvestable tree species, and (3) adopting reduced-impact logging (RIL) techniques" (Samejima et al., 2013, p. 90). Under RIL, "all targeted trees to be harvested must be selected and mapped in advance, and an efficient layout of skid trails to minimize impacts is designed before the entry of tractors… target trees are cut down with a directional felling technique… and the criteria of FSC [Forest Stewardship Council] further require monitoring the post-performance of RIL" (Samejima et al., 2013, p. 90). This is not to say that profitability and cost considerations are not important; they are. But unlike the Deramakot project which is state-run, the exercise of low-impact/low-intensity logging would be more constraining on conventional loggers who measure returns against the higher benchmark of market rates of return. Thus while the management of tropical rainforests for multiple purposes (sustaining timber yields and conserving biodiversity and ecological processes, etc.) is an accepted ideal (Schanz, 2004), the overriding objective in forest utilisation in tropical countries such as Malaysia and Indonesia remains the generation of sufficient economic rent. How much a reduction light logging (i.e., logging that removes a relatively smaller volume of timber per unit area) implies in terms of profits compared to more intensive conventional logging— this difference being the private opportunity cost— is a key factor that would influence whether or not there would be widespread adoption of low-impact logging practices and whether species like the orangutan will be kept in timber concessions. This is worth examining in detail especially since the intention is to successfully extend SFM to not only the larger landscape in Sabah, Malaysian Borneo, but it is the hope amongst conservationists to see it adopted across Borneo as a whole (Gaveau et al., 2013).[2] Where many of the orangutan populations occur, "a logged forest in Borneo is better than none at all" (Meijaard and Sheil, 2007).

In light of this, the goal of this paper is to analyse how economic returns could be balanced with orangutan conservation given the light and heavy logging regimes, and the opportunity costs associated with these. Since context is important in conservation and economic policy design, the paper starts by elucidating the Sabah state's challenge in keeping itself fiscally afloat while sustaining its increasingly depleted forestry sector and also maintaining its environmentally-friendly image, such as by sustaining its orangutan populations (Section 2). It then looks at how Sabah is hoping to extend the life of its forestry sector by introducing SFM, beginning with the Deramakot Forest Reserve project (Section 3). This section also looks at the status of the orangutan in Deramakot, including its density and population size. Next, the paper presents and discusses the profit figures of the Deramakot scheme (Section 4). Section 5 examines how RIL in Deramakot is balanced with orangutan conservation. Some possible shortcomings in the logging management plan (SFD, 2005) with regard to orangutan conservation are pointed out. The influence of the public economics factor, where politics and bureaucracy interfaces with economic planning, which is also important to whether forests are kept or not, is discussed in relation to Deramakot (Section 6). Section 7 analyses whether the opportunity cost (foregone profits) of pursuing light logging is higher than more intense logging, subject to the goal of maintaining a desired level of orangutan population. This hypothesis is tested for the case of Sabah using a general model developed by Tisdell (2012). The final section summarises and makes some concluding remarks.

[2] But see Toh and Grace (2006) for a discussion on possible opposition to such a move in Sabah.

2. Sabah's Forestry Sector and its Contribution to the State's Economy

The state of Sabah in Malaysia has 11,000 out of about 48,600 orangutans on the island of Borneo. More than 60% of the orangutans in Sabah occur within commercial production forests that have experienced repeated logging and which are still being actively logged (Ancrenaz et al., 2005). Sabah is nonetheless considered a stronghold for the orangutans (Ancrenaz et al., 2005), not only because forest loss is less rapid than in Indonesian Borneo, but also because habitat loss is curbed by Sabah's stated policy of keeping its 36,050-km^2 forest area (47% of its land area) as permanent forest estates (PFEs). Of these, 26,659 km^2 (74%) are classed as commercial forests for timber production (SFD, undated, a).[3] These commercial forests are currently divided into 23 Forest Management Units (FMUs), each with a mean area 1,000 km^2 (Ong et al., 2013, p. 2), and of which the Deramakot Forest Reserve is a part (Forest Management Unit No. 19A).

The timber industry contributes about 5% to Malaysia's gross domestic output and provides jobs for about 337,000 people (or almost 3.4% of the country's workforce) (JOANGOHutan, 2006, p. 20).[4] Sabah, together with neighbouring Sarawak, are the major timber-producing states in Malaysia, and Sabah, which has a larger number of orangutan populations than Sarawak, has been one of the biggest international suppliers of quality tropical wood in the world market at least since the middle of the 20th century. By affirming that it intends to continue to preserve its natural forest estate, Sabah appears committed to maintaining the income and employment benefits flowing from this environmental resource base into the future as well as preserving other significant social benefits that may flow from it, such as the maintenance of ecological processes such as the hydrological system and tourism value. Preserving nature complements the state tourism ministry's aim of doubling its tourism receipts in 2015 from the estimated RM4 billion for 2010 (Daily Express, 2009a). In comparison, Sabah exported in 2007 about 3.02 million $m^3$of

[3] The remainder of Sabah's forest area is divided between the following classes: protection forests, domestic forests, amenity forests, mangrove forests, virgin jungle forests and wildlife reserves. A passage from McMorrow and Talip (2001) describes the effect of the gazetting of the PFEs (or sometimes referred to as Permanent Forest Reserves, or PFRs): "The introduction of legally constituted Forest Reserves under the Forest Enactment 1968 and 1984 [in Sabah] helped to limit conversion of forest to permanent agriculture to SL [state land] and alienated land, slowing the overall pace of forest loss since the mid-1980s. The loss of natural forest outside the PFR has been dramatic. Analysis of land use tables… shows that in 1973 natural forest cover was equally distributed between Forest Reserve (49%) and land outside PFRs (51%). By 1992 forest cover outside PFRs had fallen to 15%...".

[4] However, whether this workforce is composed largely of locals or not is unclear. For instance, it is reported that about 60% of the workers working in Sarawak's wood manufacturing sector were Indonesians (Dauvergne, 1997, p. 119).

timber (logs, sawn timber, plywoods, veneer and mouldings), with a market value of RM3.4 billion (MTC, undated, a).[5]

Sabah's forestry sector, however, has been declining. During the timber boom in the 1960s, wood was rapidly harvested in Sabah to cater chiefly to the Japanese market.[6] According to Ross (2001, p. 87), "Sabah was the world's second largest supplier of hardwood logs from 1959 to 1990— second to the Philippines, then to Indonesia, and finally to its East Malaysian neighbour, Sarawak". Sabah's forests were logged unsustainably in response to the strong pressures from demand. Between 1975 and 1995, when Sabah's timber exports to Japan peaked at between 6 and almost 10 million m^3 annually (JATAN, undated), logging was 3 to 10 times the sustainable level (Ross, 2001, in Vincent and Mohamed Ali, 2005, p. 374). During this two-decade period 25,000 km^2 of Sabah's primary forests were lost (an average annual 1,250 km^2) (Mannan and Awang, 1997). Another source states that by 1993, more than 2 million hectares (ha) of forests had been logged, leaving only 413,000 ha of primary forests in the stock of commercial forests (Dauvergne, 1997, p. 105).

It has been claimed in numerous publications at various times that Sabah's forests have become exhausted. For example, it is stated that "already by about 1980, virtually all of Sabah's timber-rich dipterocarp forests had been logged or were licensed for logging" (Vincent and Mohamed Ali, 2005, p. 374),[7] but Dauverge (1997) states that from 1979 to 1988, Sabah continued to export "an annual average of around 9 million m^3 of logs, worth more than U.S.$5.5 billion" (p. 128; see also pp. 186-187 for year-by-year log output for Sabah and other Southeast Asian exporters). Although a (temporary) log ban was imposed in Sabah in 1993, ostensibly out of concern over timber depletion, this ban was not total. Rather, it was more of a reduction in

[5] But it appears that the Sabah state government's policy is to focus on palm oil production as its timber royalty dwindles (Insight Sabah, 2010). In 2008, for example, Sabah produced 5.9 million tonnes of oil palm with a market value of RM16.9 billion (an increase of more than RM4 billion from the previous year's take due to record crude palm oil prices) (IDS, undated).

[6] The first significant exports of timber from Sabah commenced in the late 1800s when it was under British rule and known as North Borneo. Between 1913 and 1919, an average 35,000 m^3 of wood were shipped overseas, mainly to Hong Kong (John, 1974). From 1924 to 1933, timber production in Sabah increased from 41,000 m^3 to almost 94,000 km^3, and concurrently, there was a shift in the primary export destination, from Hong Kong, which accounted for almost 79% of Sabah's timber exports in 1923, to rapidly industrialising Japan, which took 59% of Sabah's wood exports by 1936 (John, 1974, p. 78). Timber exports exceeded 100,000 m^3 with the approach of the 1940s.

[7] The Sabah Timber Association chairperson, Andrew Tham, was quoted to have said, in 2002: "There is no timber left. We have overlogged... there is almost no supply now" and expressed doubt over whether the state's target of collecting RM155mil from forest produce in 2002 could be met (see Sario, 2002).

production (Dauvergne, 1997, p. 118) or a "reality check" that resulted in a minor downward policy adjustment of the scale of logging and export. For instance, just prior to the ban, log production ran at an average 9.4 million m^3 per year between 1990 and 1993. During the ban that lasted from 1994 and 1996, output averaged 7 million m^3 annually (MTC, undated, b).[8] Tachibana (2000b) also provides the following figures for Sabah: 8.4 million m^3 in 1990 and 6.4 million m^3 in 1996. These figures do not reflect a drastic scaling-down that would be consistent with the repeated warnings of depletion. Log production after the ban was still considered above sustainable levels (Dauvergne, 1997, p. 118; Vincent and Mohamed Ali, 2005, p. 374). Statistics show that Sabah has been exporting between 3 and 3.5 million m^3 timber annually between 1994 and 1999, and 2.8 and 3.5 million m^3 between 2000 and 2007 (MTC, undated, a).[9] Elsewhere, it is reported that natural forest production (inclusive of logging residues) was 4.72 million m^3 in 2008 compared to 5.94 million m^3 in 2007 (Daily Express, 2009b).

The statistical data showing constant and fairly high rates of timber production appears to belie the various warnings and presumptions of a timber crash in Sabah. This could imply that either (i) the last remaining forest areas (including hill forests) in Sabah are now being liquidated (e.g., the Kuamut Forest Reserve within the Yayasan Sabah Foundation's large timber holding; Marc Ancrenaz, pers. comm., 24 Nov 2008),[10] or (ii) that official records fail to discriminate between logs taken from within Sabah and those illegally harvested in Kalimantan and smuggled into Sabah (Tacconi, 2007), or (iii) that industrial timber plantations set up in various parts of Sabah are taking up the slack from the shortfall in natural timber production.[11]

In any case, the exact extent of depletion, geographically (i.e., which areas still have timber and which do not) and quantitatively (in terms of the remaining inventories of merchantable timber and as a percentage of past levels) are difficult to obtain and verify. But as the case is with

[8] Although volume exported reduced to major importing countries like Japan, this export reduction led to large profits to the timber industry (as argued by Tachibana, 2000a). It was helped by the doubling of the price of sawn timber in the first four months of the ban (Dauvergne, 1997, p. 118). The government also made up for losses in export charges by raising fees for local processing (Dauvergne, 1997).

[9] These estimates omit chipwood production and are comprised of the main components of production, namely raw logs, sawn timber, plywood, veneer, moulding and blockboards.

[10] The Yayasan Sabah is a parastatal organization that was granted management rights over a forest concession located in the southeast portion of Sabah, measuring 10,000 km^2 or almost 14% Sabah's land area. It is one of the largest forest concessions in Southeast Asia (SEARRP, undated).

[11] There were about 2,056 km^2 of forest plantation areas in Sabah at the end of 2006 that are planted with the exotic *Acacia mangium* species (SFD, undated, b).

information regarding the location oil-palm concessions and names of concessionaires in Indonesian Borneo, there appears to be a lack of transparency on exactly what and how much timber remains in Malaysian Borneo and where.[12] Still, it is important that these details be publicly known so that appropriate sustainable forestry policies and management plans could be developed. Moreover, as market demand for tropical timber remains high with the emergence of China and India as alternatives markets to the traditional Japanese, European and American markets (ITTO, 2006), tropical timber scarcity could put added pressure on the remaining Dipterocarp forests. The question this raises is whether sustainable forest management, which requires patience, meaning, longer rotation periods, and which earn smaller initial returns from lower logging intensities, can take root in a highly demand-driven and profit-maximising climate. Market pressures may also be motivating illegal logging, which is widespread in Borneo (Tacconi, 2007), and affects even professionally managed forest areas such as Sabah's Deramakot Forest Reserve (Tay and Chong, 2005). Loggers may also be inclined to overcut their concessions in a pre-emptive move against such future risk when enforcement is lax. All this could precipitate the decline of suitable timber stands and jeopardise the establishment of sustainable forestry systems in the future that can act as an alternative to land uses involving forest clearance.

The fiscal importance of the forestry sector to the state is also important in this regard. The contribution of forestry to Sabah's state revenue can be indicative of the prospects of forestry in the state's economic policy setting relative to other industries. From 1984 to 1989, forest revenue constituted, on average, 54% of total state revenue for Sabah. This declined to 42% between 1990 and 1997, 28% between 1998 and 2000 and 20% between 2001 and 2008 (see Figure 1). More recently, it was reported that state revenue from timber has declined further, by "over 60% from RM 465 million in 2005 to RM 173 million in 2012" (Habu, 2013).

[12] Or who exactly the concessionaires and logging operators are and whether they adhere to harvesting guidelines and offtake limits. Some detailed information about timber inventories is however publicly available for the Deramakot Forest Reserve (see SFD, 2005), but this is an exception rather than the rule.

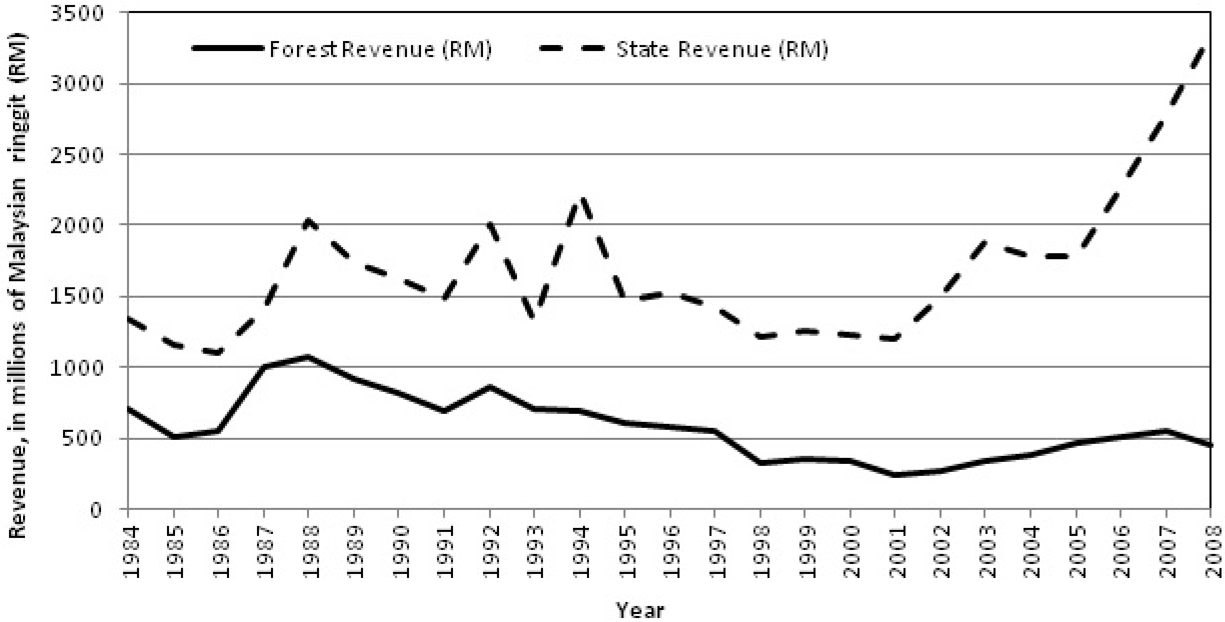

Figure 1: Sabah's forest and state revenue, compared. Revenue is stated in Malaysian Ringgit (RM) (RM1 = US$0.30 in March 2010). Data was sourced from the 2007 and 2008 annual reports of the Sabah Forestry Department (SFD, undated, c). These revenues are stated as current values.

A structural break is evident from 2001 onwards. State revenue during this period appears to have decoupled from forest revenue. This could be a result of the state shifting away from its reliance on forestry for its earnings to other industries such as the oil palm agricultural sector; indeed, Sabah has now become the largest oil-palm producing state in Malaysia. Land was converted on a large scale to oil palm in the 1990s (Henson, 2005, p. 286). By 2002, palm oil had replaced timber as the largest source of Sabah's export earnings.[13] The higher market prices of palm oil and crude oil— Sabah is also a petroleum producer— may also have accentuated this

[13]According to the Sabah Chief Minister's budget speech in October 2002, the state expected to earn for the year 2003 about RM220 million in sales tax from crude palm oil production compared to RM164.21 million in timber royalties (down from an estimated RM208.72 million in 2002) (Sabah State Government, undated, a). In 2009, palm oil's contribution to state revenue (RM708.75 million) had far surpassed timber revenue by several hundred million ringgits (Sabah State Government, undated, b). The receipt of petroleum royalties by Sabah, the other largest source of state revenue, was RM742 million for the same year. For 2010, palm oil receipts were expected to rise to RM820 million while petroleum royalties would earn the state RM647 million. Royalties and fees on forest produce, in contrast, were expected to earn only RM65.79 million for 2010.

divide. The land-use policy question is whether state decision makers view it as economical, such as in terms of rent capture, to leave forests to regenerate for a future round of timber harvesting, or whether to allow the cultivation of this cash crop on arable forest lands to cash in on the oil palm boom. This indirectly has consequences on the state's biodiversity and orangutan populations.

Given that a substantial portion of Sabah is still under natural forest cover (according to the Sabah Land Classification Code not all forest lands are suitable for agricultural conversion; McMorrow and Talip, 2001) and since Sabah's forest wildlife and environment is a tourism draw, the continued preservation of at least some amount of Sabah's forest estate would make strategic and long-term economic sense. The Sabah government is also sensitive about negative publicity from environmental pressure groups. In view of all this and at least for the present, state policymakers appear to affirm the need to continue to manage Sabah's forest cover for economic benefits as far as this is still possible (Mannan and Awang, 1997; Radin et al., 2008, p. 1).[14]

3. SFM and Orangutans in Deramakot

How then can forestry as a substantive industry and the conservation of wildlife species such as the orangutan be perpetuated in the light of possible timber depletion and the advent of oil-palm cultivation as a lucrative, alternative land-use option? A way forward that has been proposed by those with overlapping interests in forestry and forest conservation is the retention of remaining forests (Meijaard and Sheil, 2007; Berry et al., 2010) achieved through the widespread implementation of sustainable forest management (though there are different opinions about the technicalities of the timber production aspect; e.g., Sist and Brown, 2004) and ecosystem services payments (Gaveau et al., 2013). This requires a switch from the conventional, short-term approach to using tropical forests for extracting timber to the more careful and sustainable use of these forests for timber, characterised by lower logging intensities, longer rotations and

[14] A restructuring of Sabah's forestry policy ensued in 1997. Short-term logging licenses for 5-year and 25-year durations were phased out as part of the restructuring of Sabah's production forests as FMUs,and long-term logging tenures of 100 years were awarded to private companies (Mannan and Awang, 1997; Toh and Grace, 2006). As of 2010, 12 out of the 23 FMUs have been licensed out to private concessionaires; the remainder is still unleased or is being directly managed by the Sabah Forestry Department (Ong et al., 2013, p. 2). The plan is to manage these production forests for sustainable timber harvesting, reforestation, multiple uses and community development projects. However, success has so far been limited (see Toh and Grace, 2006).

the application of silvicultural techniques.[15] Balancing financial benefits with conservation goals, e.g., maintaining orangutan populations, become important considerations.

The overarching aim of the SFM approach is to cater for the multiple uses demanded by various forest stakeholders that sustains economic returns and nature conservation (Sands, 2005, Ch. 6; Kant, 2007). This ideally involves some economically acceptable level of timber production in perpetuity achieved by preserving or enhancing the natural productive and regenerative capacity of the forest even as it is logged, by retaining the necessary forest components, maintaining soil quality and mimicking ecological processes or natural disturbances as far as feasible. It also should meet nature conservation and perhaps other compatible economic goals, e.g., conserving populations of wildlife species and elements contributing to the provision of ecosystem services, and the generation of ecotourism and payments for ecosystem services. Although the goal of SFM is the co-generation of social benefits apart from income and employment benefits from timber production (Imai et al., 2009), timber extraction in practice acts as the lynchpin justifying this management approach. This is exemplified by the Deramakot case (Radin et al., 2008, p. 6).

A feature of timber harvesting under SFM is the use of reduced-impact logging (RIL), which aims to minimise the environmental impact of logging through careful pre-harvest planning and controlled implementation of forestry operations.[16] In Deramakot, where this type of logging is practiced, surveys indicate that many wildlife species, including the orangutan, continue to persist in the landscape.

3.1 The Deramakot area and its logging schemata

Logging began in Deramakot in 1956 and the area was conventionally logged till 1989. Logging intensity information for conventional logging in Deramakot is available for the years 1959 to 1968, and was 109 m^3/ha, (Imai et al., 2009), an average towards the lower end of what was

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[15]The logging of Dipterocarp-rich Southeast Asian forests has been typically characterised by the selective removal of large commercial trees with little or no regard to the damage caused to surrounding trees. This often resulted in the damage of between 50 to 75% of surrounding trees in Malaysia and Indonesia. The primary aim is the maximising of rates of return from timber sales with little concern for sustaining future forest yield or other benefits.

[16] RIL includes, but is not limited to (i) pre-harvest inventory and mapping of individual crop trees, (ii) pre-harvest planning of roads, skid trails and landings to the trees scheduled for harvest, (iii) pre-harvest liana cutting where lianas interconnect tree crown, (iv) the use of directional felling, (v) the winching of logs along planned skid trails and (v) a post-harvest assessment to evaluate the application of RIL (FAO, 2004). Logging intensities under most RIL systems aim at removing 8-10 trees/ha.

typical for logging in Sabah. In 1989, Deramakot's current management system was developed "with the intent of managing all [of Sabah's] commercial forest reserves in a way that mimics natural processes for sustainable production of low volume, high quality, and high priced timber products" (Lagan et al., 2007). In this statement of intent, sustaining timber output appears to be the primary goal; it does not mention explicit nature conservation goals and these could be secondary, though not unimportant. This is a common observation in sustainable forestry as is currently practiced (Meijaard et al., 2006). Timber harvesting operations under Deramakot's SFM system commenced in 1995. RIL harvesting, silvicultural tending and rehabilitation of degraded forests are carried out jointly by the Forestry Department and its appointed contractors. In 1997, the Deramakot Forest Reserve became the first forest in Southeast Asia to be certified as well-managed in accordance with the Forest Stewardship Council's (FSC) guidelines (FSC, undated).[17] It had undergone a third consecutive round of certification which lasted from 2008 to 2013. Deramakot is the only source of FSC-certified logs in Sabah.

Deramakot spans 551 km^2 and is located near the middle of the state of Sabah. The Kinabatangan River runs along its southern perimeter and oil palm and timber plantations are found towards the north, and on the west and east are other forest reserves. Deramakot is a mixed lowland and hill forest dominated by the merchantable Dipterocarp tree species. The topography is generally hilly and undulating. The majority of the area is comprised of logged upland forest in various stages of regeneration (SWD, 2003). The landscape is heterogeneous in terms of the number and quality of harvestable trees.

Under its SFM programme, Deramakot has been divided into 135 compartments, and these compartment boundaries were delineated according to features such as rivers, ridges and logging roads (Ong et al., 2013, p. 7). Of these, 118 compartments (516 km^2) are designated for timber production while the remaining 17 compartments (35 km^2) are termed protection or conservation areas (Figure 2) (SFD, 2005). In addition to these, it is stated that another 78.8 km^2 of such types of conservation areas are within the production area, bringing the total area protected in Deramakot to 113.6 km^2 or 21% of the total area of Deramakot (SFM, 2005, p. 39). These conservation areas comprise forests having most of the slopes above 25˚. The boundaries of

[17] The FSC is a "*certification system* that provides internationally recognized standard-setting, trademark assurance and accreditation services to companies, organizations, and communities interested in responsible forestry", whereby responsible forestry is that which adheres to the FSC's Principles and Criteria (see FSC, undated).

these conservation areas are to be protected from encroachment, and any economic activity within these compartments is prohibited. Within the 118 compartments that are managed for timber production, the net production area is 428 km^2. This net loggable area excludes land with permanent infrastructure (9.2 km^2) and further conservation areas within the production zones to be spared from exploitation that consist of riparian reserves (30 m-wide strips adjacent to permanent watercourses and swamps) (35.5 km^2) and lands with slopes greater than 25° (43.3 km^2) (SFD, 2005). The enforcement of these conservation areas is the responsibility of the Sabah Forestry Department.

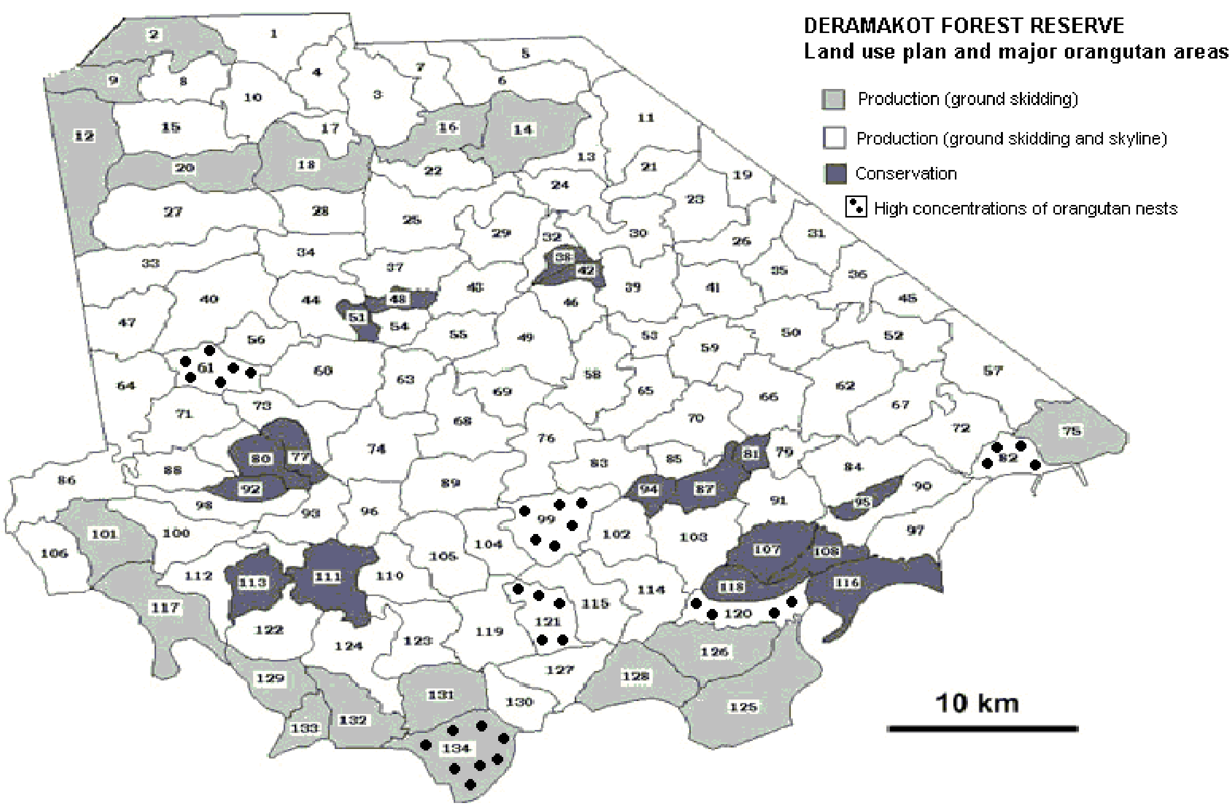

Figure 2: A detailed map of Deramakot Forest Reserve and its 135 compartments. This map was obtained from Lagan et al. (2007) and modified to highlight areas with high orangutan densities. Compartments reported to have higher concentrations of orangutan nests in 2005 are 99, 120, 121, 61, 82 and 134 (the dotted compartments) (SFD, 2005). Note that there is no overlap between these areas and compartments set aside as conservation areas.

Using visual aerial photo interpretation of the Deramakot area, the quality of the forest and the timber stock was assessed based on the criterion of the number of trees having ≥ 60 cm d.b.h. (diameter at breast height) on a per-ha basis (SFD, 2005). About 26.4% of Deramakot's total area consists of forests described as 'moderate' (Stratum 2) or 'good' (Stratum 1) forests (having 9 to 16, or more than 16 trees of ≥ 60 cm d.b.h. per ha, respectively). About 73% of the area consists of 'very poor' (Stratum 4) and 'poor' forests (Stratum 3) (containing 0 to 4, or 5 to 8 trees of ≥ 60 cm d.b.h. per ha, respectively). Stratum 5 (shrubs and grasslands) make up 0.13% of the area. Only 20% of Deramakot's area is considered well-stocked with harvestable trees (i.e., having at least 15 harvestable trees/ha) (Radin et al., 2008).

Trees that are targeted for harvesting are those between 60 to 80 cm d.b.h. (SFD, 2005, p. 26). The Deramakot Forest Management Plan for 2005-2014 aims to extract 9 such trees per ha, and to determine when a compartment is adequately stocked to justify a harvest, a minimum economic cut of 40 m^3/ha is used (SFD, 2005, p. 30) (but an actual yield per compartment is about 25 m^3/ha on average was observed in the earlier term of the management plan; Radin et al., 2008, p. 8).[18] The number of compartments identified to have sufficient numbers of suitable trees to be harvested in the current 40-year harvesting cycle is 86, covering 367 km^2 (SFD, 2005). This equates to a gross annual harvestable area of 9.17 km^2 on average (SFD, 2005, p. 26, 31). Forest management activities are thus to be conducted over roughly 10 km^2 annually over the 40-year cycle (SFD, 2005). The plan assumes that only 48% of this area actually has trees that can be harvested (the average proportion calculated from the previous planning period; SFD, 2005, p. 31), the net annual harvestable area becomes 4.4 km^2. This latter value, when multiplied by the chosen minimum economic cut of 40 m^3/ha, gives the current planned, annual allowable (maximum) cut for Deramakot of 17,600 m^3. Since Deramakot is a relatively degraded site, silvicultural treatments are applied to enhance the regrowth of commercial timber species. These treatments include enrichment planting (the planting of commercial timber tree seedlings) and the removal of weeds and non-commercial trees from near potentially valuable timber trees.

[18]Different compartments are harvested at different intensities, ranging between about 15 and 49 m^3/ha (Radin et al., 2008, p. 10), depending on the availability of suitable trees and their quality, among other reasons including technical ones (see Radin et al., 2008, p. 9).

3.2 Orangutans within Deramakot

The orangutan is one of a number of indicators used for monitoring forest health in Deramakot. Deramakot is said to harbour one of the highest recorded densities of orangutans in an actively logged lowland Dipterocarp forest (Payne and Prudente, 2008, p. 145), although other studies in formerly logged areas in Indonesia reveal even higher densities (e.g., 3 individuals/ha) (e.g., Marshall et al., 2006, pp. 572-573).

Surveys indicate that a "[s]ignificantly high number of nests was sighted in the southern part of DFR (disturbed habitat)" (SFD, 2005; see Figure 2). These disturbed habitats in the south fall under the category of poor forests as described earlier. Nest concentrations are low in the very poor forests and shrubs and grasslands of Deramakot, and are intermediate in the moderately well-stocked forests found in the northern segment (SFD, 2005). A more recent survey showed that orangutan nests are located throughout Deramakot, especially across the central area and southern area (Takyu et al., 2013, pp. 119-124). Since orangutan distributions are known to fluctuate based on the spatial occurrence of fruiting in a forest (e.g., Buij et al., 2002), the difference in orangutan distribution between the northern and southern parts of Deramakot is believed to be due to the higher fruit productivity in the more disturbed forests found in the south than in the less disturbed forests elsewhere (SFD, 2005),[19] and because of more fruiting events in trees closer to the Kinabatangan River in the southern part (SWD, 2003). Lower densities of orangutan nests such as in the northwestern are also attributed to the presence of roads and proximity to oil-palm plantations (Takyu et al., 2013, p. 124). Orangutans have been observed to commonly nest on pioneer tree species such as the Binuang (*Octomelessumarana*) and Laran (*Neolamarkiacadamba*) that grow along the streams in Deramakot (SFD, 2005) (the findings of Ancrenaz et al. (2010, p. 6), from a different production forest in Sabah, suggests that "these pioneer plants", such as Laran, "are supplying new and alternative food sources that buffer periods of food scarcity").

[19] A reason offered for this is that after climax tree species are felled, pioneer tree species replace climax tree species and that these pioneer tree species fruit more frequently (Ancrenaz et al., 2010, p. 6).

The Deramakot Management Plan states that the Forestry Department (SFD, 2005, p. 53):

> "will have to ensure that corridors connecting refuges… will be provided to allow free movement of animals in either direction. This means, logging operations will be minimal and will not take too long within the wildlife corridors, particularly in Cpts. 12, 14, 34,55, 86, 88, 110, 119, 123, 124, 131, 132, and 135, which are classified to have higher value for the HCVF [high conservation value forests]."

These compartments, however, are not those identified in Figure 2 as areas containing significant numbers of orangutan nests.

Information is lacking for making judgement on the degree of conflict between the use of trees by orangutans and the extraction of these trees for commercial logging (e.g., whether a small or large proportion of these commercial crop trees are used as important food sources by the orangutan). While some studies indicate that orangutans build nests mainly on tall trees or trees with large basal areas such as Dipterocarp trees (Ancrenaz et al., 2004), the literature is unclear on how seriously orangutan populations are affected by the logging of these commercial trees whether under RIL or otherwise.

Orangutan species or subspecies have been observed to adapt differently to logging (Marshall et al., 2006, p. 576), the *P.p. morio* subspecies found in Sabah and East Kalimantan thought to be better able to cope with logging than *P.p. wumbii*and *P.p. pygmaeus* in the south of Borneo (Central Kalimantan) and towards the northwest of the island in west of Kalimantan and Sarawak. Although this argument may be used to justify the appearance of stability in orangutan populations and their overall densities in Deramakot in the face of logging activity (Table 1), this presumption hinges on the relatively short-term average data for Deramakot. It does not, for example, track differences in densities between logged and unlogged areas or consider the fragmenting effect of logging on different sub-groups of the population. No definite trend can be made out from these published general density data, or for specific orangutan areas within Deramakot. The results of a survey by Ancrenaz et al. (2005) seem to show that although overall orangutan densities for Deramakot averages 1.50 orangutans per km^2, close to the average of the densities presented in Table 1 (1.53 orangutans per km^2), and the confidence interval ranges from 0.55 to 4.05 orangutans/km^2. The corresponding population size is 792 orangutans, with a confidence interval of 292-2,148 individuals (the average from Table 1 is 845 orangutans). This suggests a highly clumped and varied orangutan distribution across the Deramakot landscape.

Table 1: Average orangutan densities and numbers, as estimated by the Sabah Forestry Department for Deramakot Forest Reserve between 1999 and 2005 (Table 10 in Radin et al., 2008).

Date of orangutan census	Number of individuals/km^2	Number of orangutans
December-99	1.40	772
July-02	1.78	981
December-02	1.71	943
December-03	1.65	910
February-04	1.74	959
June-05	1.64	904
November-05	1.10	607
June-06	1.23	678
November-06	1.18	651
August-07	1.50	827
November-07	1.92	1,059

Variations in orangutan numbers and densities between parts or compartments may be partly explained by whether an area is logged or not and the quality of the remaining timber stands, since orangutan build fewer nests "in compartments that have been highly exploited", and that they preferentially "nest in places where large trees are still abundant" (SWD, 2003). The retention of patches of good forest within an exploited area as a sort of refuge is thus seen as beneficial. It is opined that the RIL approach in Deramakot is probably crucial for maintaining stable and viable orangutan populations as long as there is no hunting pressure on the species (Marc Ancrenaz, pers. comm., 24 Nov 2008).

4. The Profitability of Timber Harvesting at Deramakot

The timber revenue, cost and profits from the Deramakot project between 1995 when RIL operations began until 2008 are presented in Table 2.

Table 2: The volume of timber harvested, the average log auction price, annual revenues, costs and profits for Deramakot from 1995 to 2008 (compiled from Radin et al., 2008). Financial figures are quoted in Malaysian Ringgit (RM) (1 US$ equals RM3.3, as of 13 January 2014).

Year	Planned annual allowable cut (m^3)	Actual volume cut and sold (m^3)[a]	Average price (RM/m^3)[a]	Revenue (RM, in millions)[b]	Cost (RM, in millions)[b]	Profit (RM, in millions)[b]	Profits per km^2 (RM, in millions)[c]
1995	20,000	189	270	0.051	4.62	-4.57	-0.457
1996	20,000	13,277	267	3.47	5.30	-1.83	-0.183
1997	20,000	13,794	245	3.39	5.20	-1.81	-0.181
1998	20,000	12,236	396	4.84	6.60	-1.76	-0.176
1999	20,000	915	1,004	0.92	5.03	-4.11	-0.411
2000	15,000	12,928	468	5.82	8.40	-2.58	-0.258
2001	15,000	12,675	339	3.61	5.77	-2.16	-0.216
2002	15,000	16,882	468	7.73	5.12	2.61	0.261
2003	15,000	14,555	552	8.03	5.92	2.11	0.211
2004	15,000	19,821	554	10.99	4.94	6.05	0.605
2005	17,600	11,425	614	7.01	4.51	2.50	0.250
2006	17,600	16,129	705	11.53	6.53	5.00	0.500
2007	17,600	13,363	809	11.14	6.67	4.47	0.447
2008[d]	17,600	(n/a)	(n/a)	9.00	5.30	3.70	0.370

[a] Table 5 in Radin et al. (2008); [b] Table 13 in Radin et al. (2008); [c] calculated using the average gross area harvested in a year in Deramakot (10 km^2); [d] a projection for the full year.

The main revenue component is the revenue earned from selling the logs produced at Deramakot at a green premium, that is, at a higher price on grounds of their sustainable production. The main cost components are "the harvesting operation estimated at 36.8% of the total cost, followed by the general administrative cost at 18.8%, forest restoration at 15.5%... [the] acquisition of new machineries at 9.1 %" and "logging road costs… estimated at 8.3 %" (SFD, 2005, p. 72). These costs are borne by the Sabah Forestry Department and the profits from log sales go to the government. Private loggers are contracted to carry out the harvesting.

Losses were recorded in Deramakot's annual operations until 2002, when an annual profit was first made (RM2.61 million). Between 2002 and 2008, annual profits ranged between RM2.11 million (or RM211,000 per km^2) and RM6.05 million (RM605,000 per km^2). Cost and revenue projections for Deramakot between 2010 and 2014 presume annual profits ranging between approximately RM1.3 million and RM 4.8 million (Appendix 13 in SFD, 2005).

Nonetheless, conventional logging with its typically higher logging intensity would produce higher profits in forests which still have good stocks of merchantable timber, especially initially, in the first few logging cycles, after which returns would dip as a result of forest exhaustion (forest managers then have the option to convert these degraded forests to timber or agricultural plantations to sustain high returns).[20] By the yardstick of the financial return to investment, the internal rate of return (IRR), conventional logging would usual surpasses SFM in the near- to mid-term. The merit of SFM lies in the fact that returns in principle could be sustained over more than two logging cycles compared to conventional logging, although returns may be initially lower than for conventional logging (Pearce et al., 2002; van Gardingen, 2003).[21] However, the perceived upfront opportunity cost is high enough to deter the widespread adoption of SFM under free market conditions.

It is argued that the timber premium that RIL-certified logs fetch, such as in Deramakot (Lagan et al., 2007, p. 414; Kollert and Lagan, 2007), or returns from other direct and indirect use values of the exploited forests (e.g., ecotourism, the harvest of non-timber forest products, or carbon sequestration earnings) (Pearce, 2007; García-Fernández et al., 2008), would make such low-intensity logging worthwhile. But such presumptions may only apply in limited cases. Consider the following: can a green premium be sustained if sustainable forestry is widespread and there is a flood of green timber in the market? Moreover, according to one source, increases in world timber prices would barely exceed 1% over the next 60 years even under a high-demand scenario (see Pearce et al., 2002, p. 28). Or can sustainable forestry remain viable if major tropical log importers choose to import cheaper and unsustainably produced logs of comparable quality (Price, 2007)? It may be that the price premium would apply to a niche market and may not be viable for catering to the general demand for timber.[22]

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[20] If the timber stock is made up of a fairly large proportion of lower-quality timber trees such as in degraded forests, the difference in earnings between conventional logging and SFM may be smaller. Revenue from conventional logging in such cases could also decline with higher annual cuts because the marginal cost of accessing low-quality timber could exceed (because of roading costs) the marginal financial gain from timber sales (e.g., Mathey et al., 2009).

[21]Although only RIL without the necessary reductions in harvesting intensity would not guarantee this (see Putz et al., 2008).

[22] Certification is a broad set of principle and does not guarantee that any given wildlife species or and biodiversity in a specific area will be conserved. The warm-glow feeling that consumers derive from purchasing certified timber products, believing that they have contributed to conservation, may be misplaced as a result (for a discussion, see Price, 2007).

5. A Discussion of the Viability of Deramakot's SFM Model for Orangutan Populations

There is a shift from the focus on the production of private goods such as timber to the co-provision of public good in forestry, at least in the case of Deramakot Forest Reserve. However, there may be a conflict between maintaining the supply of public goods on logged areas and the goal of producing market goods for profit. This problem is obvious in the case of the orangutan and logging in Borneo, where the main issue is the compatibility of wood production goals with non-timber production goals.

Although Deramakot is described as an SFM project (SFM ideally being a relatively balanced use of forests for multiple uses), it is centred on RIL, the aim of which is to sustain timber production by reducing logging damage to residual stand of trees, improving the cost-efficiency of timber harvesting, and the application of silvicultural treatments that improve future harvestable timber volume.[23] To be sure, Deramakot's RIL is being conducted over the commonly recommended 40-year cutting cycles and although the stated harvesting intensity of 9 stems/ha is higher than the limit prescribed for Southeast Asia and Borneo (8 stems/ha or less; Sist et al., 2003a, b), in practice fewer stems are removed on average. A study by Marshall et al. (2006) in Indonesian Borneo suggests that taking 5 stems/ha or less should not have any significant negative effects on orangutan numbers. Having said that, RIL on its own does not constitute SFM; RIL's value for biodiversity conservation or sustaining ecological services is general and is not specific to any wildlife conservation goal unless SFM and RIL takes account of the ecological requirements of a species targeted for conservation. This applies to orangutan conservation. Additional (and possibly costly) measures may need to be instituted that ensure the

[23]The policy statement in the second forest management plan for Deramakot (SFD, 2005) explains that the Sabah Forestry Department (SFD) "would maintain and enhance the high conservation value forests, biodiversity, wilderness, soil, and water resources that are ecologically justified, technically and financially feasible within the framework of the SFD's regular operations". It is also stated that "[e]very effort would be undertaken by the SFD to optimize economic returns to the State on a long-term basis by maximizing utilization, efficient use of raw materials from DFR, and good marketing strategies of DFR's [Deramakot Forest Reserve's] ecotourism potentials". The long-term management objectives stated are specific about the silvicultural aspect, viz., "[t]o sustain production of high value timber based on an annual allowable cut (AAC) of 17,600 m^3 and reduced impact logging (RIL) while maintaining a high degree of species and structural diversity", "[t]o carry out silvicultural tending (10,000 ha) during the plan period…", "[t]o restore 2,000 ha during the plan period, in the southern part of DFR where stand stockings are absent or inadequate", but are vague for the environmental ones : e.g., "[t]o integrate all forest operational activities within the concept of conservation and protection so as to reduce the impact to the environment from fire…", "[t]o maintain the ecosystem diversity at all levels for wildlife habitats, education, research, and eco-tourism purposes", "[t]o maintain and enhanceHCVF [high conservation value forest] sites". The plan does not mention or stipulate assessable variables for monitoring environmental objectives.

orangutan’s (and other vertebrate fauna’s) long-term viability in the logged areas, which could include maintaining contiguous undisturbed patches of forests in the logging area, ensuring forest connectivity through natural forest corridors, preserving food sources such as figs and nesting sites (e.g., Meijaard and Sheil, 2008).

Although the compartments earmarked as conservation areas in Deramakot are claimed to be “set aside for biodiversity conservation” (Mannan et al., 2008, p. 8), it appears that these steep and high-elevation areas were selected on the basis of the slope limit specified by RIL guidelines, which itself is conceived out of concern for costs of access and transport and erosion or watershed damage (Applegate et al., 2004, p. 11) rather than purely for conserving biological diversity. These areas would in any case be uneconomic to harvest. Insofar as the orangutan is concerned, these strictly conserved compartments are not those areas identified as significant orangutan-populated areas (see Figure 2). But to the Deramakot management plan’s credit, high-conservation-value forests are identified within certain compartments and excluded from logging, based on their importance as representing key swamp vegetation, critical ecological resources such as riparian zones and important wildlife habitat (SFD, 2005, p. 39, pp. 52-55), including saltlicks which animals such as the orangutan rely on for minerals (Takyu et al., 2013). Moreover, fig plants, which usually grow on Dipterocarp trees and are important food sources for the orangutan, are reportedly not cut at all. In Deramakot, woody vines are left uncut over buffers of 30 metres on either side of permanent streams (Ong et al., 2013, p. 16). These measures could be beneficial to the orangutan but they impose additional management and opportunity costs that could reduce short-term profits.

Yet, there is no information on which, how much or whether the areas where most of the orangutans are found in Deramakot are strictly conserved. It is probable that key habitat areas are not strictly conserved even if they are considered high-value conservation forests (Radin et al., 2008). Note also that areas with significant numbers of orangutan nests fall outside the designated conservation areas (refer Figure 2). Another issue that remains open to question is the eventual trajectory of the size of the orangutan population based on the anticipated quality of successive forest stands for orangutan use (or for that matter, for the use of other wildlife species). This concern arises from the focus on producing commercial tree species and removing some competing non-commercial tree species; if food trees are reduced in new forest regrowth, this might be a problem for orangutan persistence in the future. There is also a lack of mention in the Deramakot management plan about the identification, mapping and retention of orangutan food trees (SFD, 2005). Though some trees known to be used by the orangutan such as the Durio (durian) species are classified as “prohibited species”, i.e., species that cannot be legally taken in harvesting operations (SFD, 1998, p. 35), whether these and (trees having orangutan nests) are left undamaged in practice is uncertain. Thus while densities of orangutans and their numbers appear stable (Table 1), the long-term trajectories of the populations given current logging practices is not certain but could modelled.

Where SFM is practiced, the prescribed limits to the number of trees (or volume of wood) that can be taken per hectare can still impose stresses on orangutan populations. For example, where many harvestable timber trees are clumped close together in a given hectare, for example, their removal could still create canopy gaps that can hinder orangutan movement and impede the regeneration of commercial or canopy/climate tree species, not to mention the reduction of adequate densities of seed trees (Brown and Press, 1992; Meijaard et al., 2005, p. 37). SFM that strictly observed rules for maintaining biodiversity would have to endure the opportunity cost of leaving behind some timber trees that are perfectly harvestable under RIL rules.

More generally there are issues that need to be considered before extending SFM to the larger orangutan landscape in Borneo. Some of the highest orangutan densities are found in peat swamp forests, e.g., the Sebangau region in Central Kalimantan (Husson et al., 2009, p. 93). These types of forests pose a problem for forestry. Because most minerals that are required for new tree growth are found in living organic matter and recently decomposed dead organic matter of trees, regeneration of trees in peat swamps is possibly very slow (van den Eelaart, undated). The potential for natural forest management as a means to conserving the orangutan in such instances are poor. The absence of this option leaves peat swamps more vulnerable to illegal logging and agricultural conversion.

The following sections consider the public economic aspects of the viability of the Deramakot SFM model, the economic viability of extending the Deramakot model to other orangutan habitat and a suggestion for partitioning logged forests for conserving the orangutan while offsetting the opportunity cost of doing so.

6. Public Economics as a Determinant of the Viability of Deramakot's SFM

Because forestry has been the mainstay of Sabah's modern-day economy, Sabah's forestry agency has long been in charge of administering vast areas of land in Sabah for timber production. It remains a relatively large and influential bureaucratic body despite the declining fortunes of the local forestry sector. If the level of revenue obtained by the Sabah Forestry Department is not sustained, this threatens not only the reputation but the size of this department's budget, its relative political power within the government, and the tenure of its bureaucrats.

The department thus faces a dilemma: it may choose to have more revenue now by continuing to unsustainably exploit what remains of its forest estate at the expense of a large drop in projected future revenue and so being subject to budget reductions, or it could moderate its earnings now to sustain revenue at a similar or higher level later when the forest's timber stock replenishes. Niskanen's (1994) public choice theory proposed that there is a tendency for government departments to act in ways to prolong their survival and increase its welfare by aiming to maximise its discretionary budget. This may partly explain the reason why Deramakot and the rest of Sabah's degraded production forests are still retained for forestry purposes and not converted for obvious profitable land-uses such as for oil palm when this is possible and given Sabah's emphasis on increasing oil palm output to sustain state revenue. To remain relevant and to save the department's budget from large cuts, the Sabah Forestry Department has sought to rehabilitate Sabah's production forests under its sustainable forest management with an approach that combines lower-impact logging and natural regeneration of degraded forest areas that is supported by liberation thinning but also increasingly through enrichment planting to restock areas depleted of commercial species.[24]

Deramakot is seen as a model for testing the sustainable forest management approach. It would contribute to the Forestry Department's credentials if Deramakot can show that it is at least not a financial drain on the state and that it can generate revenue on a sustainable basis while also being environmentally-friendly, thereby securing public support as well. Therefore the

[24]A Sabah Forestry Department officialrevealed that there is less reliance on natural regeneration in many of Sabah's production forests because of the large amounts of degraded timber stocks (Robert Ong, pers. comm., 21 Nov 2008). Enrichment planting has been attempted, which is a costly operation.

conservation of wildlife species such as the orangutan may be symbolically important for Deramakot. Also, bureaucratic support from other benefitting departments such as the tourism department aid in countering the lobby of other competing interest groups and government departments such as those aligned with the oil palm sector.

Recall that Deramakot is a state-run project. As a government project, making large, short-term profitmaking need not be an overwhelming concern; the priority would be to sustain government revenue and possibly also to provide other non-financial benefits to the state and its people. Therefore although Deramakot does not generate returns comparable to conventional logging or agricultural conversion, its viability is supported by a historically influential forestry-linked bureaucracy. There is, however, evidence that the Forestry Department is under pressure to release timber production forests for the establishment of oil-palm or timber plantations (see McMorrow and Talip, 2001), and allegations of illegal logging in the production forests under the supervision of the Forestry Department that might be related to politics (e.g., Habu, 2013).

7. Should Orangutan Habitat Area be Protected and Higher Intensity Logging Conducted AroundThese, or Should the Area be Mostly Lightly Logged?

The Deramakot case leads us to consider whether economic and environmental benefits are better optimised by using the forest in a spatially specialised manner, i.e., applying higher intensity forestry in a part of the forested area combined with the total protection of the remainder, or by managing the landscape mainly as a forestry matrix where reduced-intensity sustainable forestry practiced throughout the forest while accounting for biodiversity. This inquiry follows from Ashton’s (2008, p. 290) assertion that the challenge in forestry is to determine

> “How… conservation and continued timber production [can] together be optimally combined, on both economic and ecological criteria… and [a]re they better achieved by modifying logging procedures to accommodate biodiversity conservation requirements, or by setting aside strict conservation virgin jungle reserves while managing elsewhere for optimal sustainable timber production?”

Conservationists have not addressed this question analytically, such as by the use of economic models. This section is an attempt to answer this question by assuming a scenario involving a typical primary forest or a forest with a relatively good stock of timber in Sabah that is populated by orangutans, and which undergoes one round of logging per sixty years (following Tay et al., 2002). This exploration is enabled by applying Tisdell's (2012) simple model for comparing the opportunity costs of different logging regimes given the constraint of conserving a single wildlife species.

7.1 The model

The hypothesis to be tested using this model is whether it is more economic to conserve a viable population of orangutans by (i) setting aside important orangutan habitat areas as protected areas within a timber concession and logging the remaining area of the timber concession area at a relatively high logging intensity, or by (ii) lightly logging a large portion of the timber concession area— the area that could have been strictly protected for orangutans, as well as part of the area that could have been more intensely logged— thereby reducing the amount of area that would be more intensely logged. This model, even if it is a static analysis, is relevant since light logging involves the opportunity cost of foregoing more intensive logging and the problem can be reduced to balancing forestry uses while also finding ways to conserve wildlife, and is useful for obtaining estimates as a first indicator to guide forest-use planning. The two options just mentioned are graphically illustrated in Figure 3.

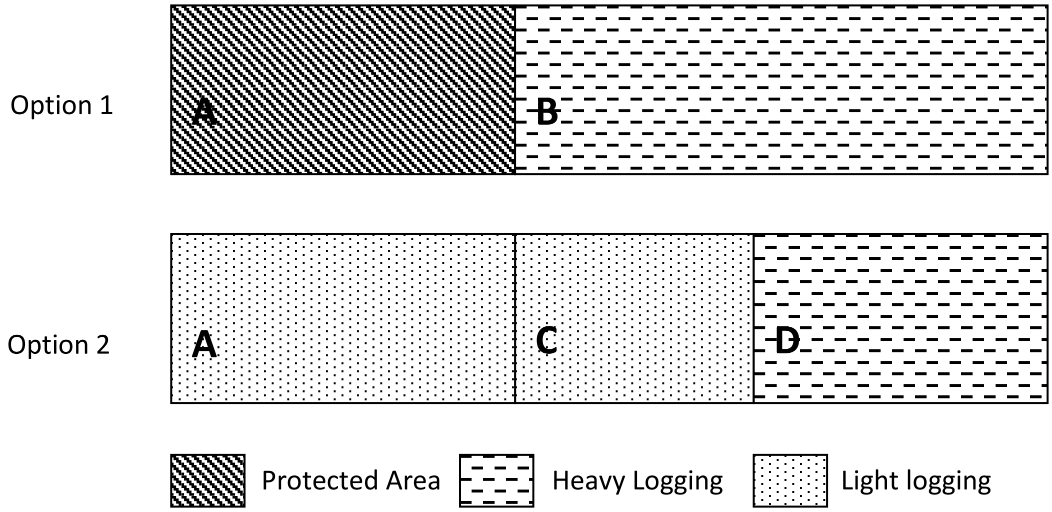

Figure 3: Options for conserving orangutans under two different logging regimes (from Tisdell, 2012). Under Option 1, significant orangutan habitat area A is protected from logging whereas the remainder of the total timber concession area, B, will be logged heavily (or at an intensity that is higher than SFM). Under Option 2, the whole concession area is open to logging but area A+C is lightly logged to support orangutans, and a smaller area D is more intensely logged.

The change in total profit by selecting Option 2 rather than Option 1 would consist of the additional profits gained from logging area A, less the reduction in profits as a result of logging area C lightly rather than heavily. In Option 1, Area A conserved K number of orangutans, where K is the targeted viable population of orangutans. In Option 1, K occurs on the area A. In B, the orangutan is presumed not to persist because of the heavy logging conducted there. Such types of heavy logging would include those that extract more than 100 m^3 of timber per ha.[25] In Option 2, K occurs over area A and C. Heavily logged area D is presumed not to harbour orangutans. In Option 1, the size of protected area A for conserving orangutans would be K/λ_P km^2, where $\lambda_P$is the density of orangutan in the protected area. In Option 2, the size of lightly logged area A+C for orangutans would be K/λ_L km^2, where λ_L is the density of orangutan in the lightly logged area. The area marked C would therefore be equal to $(K/ \lambda_L) – (K/\lambda_P)$ (see Tisdell, 2012, p. 16).

[25]Ancrenaz et al. (2010, p. 7) found that logging intensities of above 100 m^3 per ha, which correspond to the intensities of conventional logging, had caused the localised extinction of an orangutan subpopulation in the North UluSegama forest.

If the profit from heavy logging is Π_H per km^2 and the profit from light logging is Π_L, then the total change in returns from logging when Option 2 rather than Option 1 is implemented, denoted by ΔR, can be described by the following formula:

$$\Delta R = \frac{K}{\lambda_P}\prod_L - \left(\frac{K}{\lambda_L} - \frac{K}{\lambda_P}\right)\ (\prod_H - \prod_L) \qquad (1)$$

The first term on the right-hand side of this equation represents the increase in profits from lightly logging area A which was protected (Figure 3), and the second term is the fall in profits resulting from not heavily logging the area C. If ΔR is negative, then that means that the light logging option is less rewarding financially than Option 1, and vice versa. If all else is equal, the likelihood that ΔR is negative is greater (i) the smaller is the per-km^2 profit under light logging, Π_L, and (ii) the smaller is λ_L relative to λ_P (because then the coefficient $\left(\frac{K}{\lambda_L} - \frac{K}{\lambda_P}\right)$ becomes larger). Similarly, the likelihood that light logging, Option 2, generates a greater return than Option 1 increases (i) the smaller is the fall in the density of orangutan under light logging when compared to no logging (e.g., the more robust orangutans are to persisting under light logging) and (ii) the smaller is the reduction in profits from logging per km^2 under light logging compared to heavy logging (e.g., the greater the premium for lightly-logged timber).

The goal here is to assess whether conducting Option 2 (light logging) in the broader production forests of Sabah is more financially attractive than reserving a protected zone for orangutans and more heavily logging the surrounding forested area.

7.2 Data

The model partly uses the Sabah Forestry Department's data for Deramakot that were presented earlier and from locations adjacent to Deramakot from other secondary sources.

Even though the scenario to be modelled here presumes a primary or well-stocked forest in Sabah, and Deramakot is an area that has been logged a number of times in the past, the profit data for light logging of Deramakot could still be applied: the same nine trees per hectare that are harvested in Deramakot for a more or less 40 m^3/ha timber volume could be replicated in a well-stocked forest so that it is compatible to sustaining orangutans. The same prices for logs are also assumed. Thus the profit estimate for light logging here uses the Deramakot data from Table 2 for 2007 (the data for year 2008 is a projection).

While Deramakot offers rare data for the case of light logging that involves orangutans, there is a greater dearth of data for suitable profit estimates for conventional logging. Care should be exercised in the use of profits for very different locations and time periods.[26] While Tay et al. (2002) provide conventional (heavy) logging profit estimates for the case of a primary forest in Ulu Segama, Sabah, which is part of the Ulu-Segama-Malua production forest complex located on the southeast of Deramakot and which would fit the scenario adopted here, Tay et al.'s (2002) profit estimate of RM7,715 per ha (for a timber volume of 136 m^3 per ha) dates from the year 1993. The best that can be done is to inflate this profit estimate to 2007 prices so that it corresponds with that light-logging profit estimates for Deramakot. Using an average Malaysian inflation rate of 2.71% from 1993 to 2007, to convert 1993 data to 2007 monetary values, this profit estimate for conventional logging becomes RM11,218. The year 2007 is chosen to correspond with the data obtained for Deramakot (see Tables 1 and 2).

The orangutan density under light logging that is used is the average for Deramakot up to the year 2007 (see Table 1). For orangutan density in a relatively undisturbed forest area, the data from the Ulu Segama forest concession in Sabah, which is not far from the Deramakot Forest Reserve, is used (the data is obtained from Ancrenaz et al., 2010, p. 6).

A target orangutan population level of 845 individuals is assumed. This is considered a viable orangutan population size (subject, of course, to various ecological conditions) (e.g., Meijaard et al., 2012, p. 38). It is the average orangutan population size in Deramakot based on the data presented in Table 1, and is a midpoint between the reported average population of 792 orangutans in 2005 (Ancrenaz et al., 2005) and the more than 1,000 reported for 2008 (Radin et al., 2008). The data to be adopted for the model are summarised in Table 3. The data assumes that the area A under consideration would span 422.5 km^2 (2 orangutans per km^2 divided by 845

[26] Logging profits vary tremendously from location to location, given the heterogeneity of tropical forest stands and type of woods, but also due to the differing cost and organisational structures involved (i.e., from whose perspective the profits are estimated— e.g., the private logger, or the concession holder who contracts out logging to the private logger). Generalisations are therefore impossible (John Tay, pers. comm., 15 January 2014). Nonetheless, some reasonably close estimates have to be adopted for rough comparisons.

orangutans) and the area A+C would equal 563.3 km^2, where the size of C is the difference between these two values (140.8 km^2).

Table 3: The variables used in the model for assessing changes in the profit of different logging regimes, and their values.

Variables	Symbol	Values	Units	Remarks
The target level of orangutan population	K	845	Orangutan individuals	Above (conditional) minimum viability size of 500 for orangutans (Meijaard et al., 2012); average population size in Deramakot (from Table 1)
Average orangutan density in comparable protected forests or forests not recently logged	λ_P	2	Orangutan per km^2	Ancrenaz et al. (2010, p. 6)
Average orangutan density in lightly logged forests	λ_L	1.53	Orangutan per km^2	Average of the densities in Table 1; also see Ancrenaz et al., 2005, p. 2)
Average profit from heavy logging	Π_H	1,121,800	Malaysian ringgit (RM) per km^2	Inflation-adjusted to year 2007, from Tay et al. (2002)
Average profit from light logging	Π_L	447,000	Malaysian ringgit (RM) per km^2	For year 2007 (see Table 2)

7.3 Results and interpretation

Applying the data above to equation (1), it was estimated that the change in returns from adopting Option 2 rather than Option 1 over the total forest area presumed here is positive, at RM93.8 million. This means that for the conditions described in Table 3, light logging would be the economically preferable option. Next, using the Goal Seek function in the *Microsoft Excel 2007* software, a sensitivity analysis was conducted to determine the values for the variables in Table 3 that would produce a ΔR of zero (see Appendix). In this sensitivity analysis, Π_L, Π_P, λ_L and λ_P were varied. It was found that given all other base case variables are constant (those listed in Table 3), Option 2 would be preferable from a profit perspective as long as:

(i) Average orangutan density in the undisturbed or protected area is below 2.49 orangutans per km^2,

(ii) Average orangutan density under light logging remains above 1.20 orangutans per km^2,

(iii) Average profits from heavier logging is below RM17,800 (US$5,394) per ha, or

(iv) Average profits from light logging are larger than RM2,805 (US$850) per ha.

These findings mean that if a light-logging regime is to be economically attractive, it should not result in a great fall in orangutan density in a forest following logging. Based on the scenario modelled here, as long as the average density observed after light logging similar to what was recorded for Deramakot is maintained, then light logging would be the more profitable option if all other variables are held constant. Given this same density, if the original average density prior to light logging was 2.49 orangutans per km^2, and above, it would be better to choose Option 1. But average densities greater than 2.49 orangutans per km^2 is rare in Sabah's orangutan landscape; a survey of Sabah's orangutan habitats (Ancrenaz et al., 2005) revealed that only the Kulamba Wildlife Reserve (size: 207 km^2), located on the east coast of Sabah and away from the central forested region where Deramakot is located, has 2.50 orangutan per km^2 on average. The Ulu Segama-Malua production forest adjacent to Deramakot has maximum average densities of mostly 2 orangutans per km^2 (except for the Sabah Biodiversity Plot there, which recorded 2.4 orangutans per km^2) (Ancrenaz et al., 2010, p. 5, 9). Hence, given such average densities, the likelihood of Option 2 being more economically attractive is higher.

There may be some reduction in orangutan density immediately following logging as orangutans vacate the area to seek refuge in nearby forests that are not being disturbed, but the findings of Ancrenaz et al. (2010, p. 6) suggest that orangutan densities in slightly logged forests that are regenerating can recover to densities that are close to pre-logging densities. Husson et al. (2009) also report that forests that have undergone selective logging, where a small number of valuable timber trees per forest plot are taken while sparing important fruit trees for the orangutan, seem to support similar densities of orangutans as in unlogged forests. These findings support the argument for adopting Option 2-type logging.

Profit from heavy logging has to be 59% higher than the profit reported by Tay et al. (2002) for Option 2 to be unattractive relative to Option 1. The cut rate on which Tay's estimate was based was 136 m^2 per ha, which is a high rate of extraction. It would be quite unlikely for profits from conventional logging to exceed this profit level unless natural timber prices rise substantially, the prospects of which is slim (refer to Section 4). In somewhat degraded timber concessions like Deramakot, it is not possible to extract very large number of trees per ha by conventional logging. Thus, as long as an appropriate premium can be obtained for lightly-logged timber which could produce a light-logging profit of above RM2,805 per ha (which Deramakot has demonstrated for four years out of seven between 2002 and 2008), Option 2 would be preferable.

While “many conservationists find it difficult to entertain the notion of protecting a species in a forestthat is not managed primarily for conservation purposes… even if orang-utans can survive in such habitats” (Ancrenaz et al., 2010, p. 7), the findings here suggest the following: that for a case similar to the conditions of Deramakot and Ulu Segama forests in Sabah, where the pressure to exploit orangutan habitats is great, light logging is more likely to be economically attractive than an option of strictly protecting orangutan habitats which could result in heavier logging elsewhere to recoup foregone profits. These findings are subject to the profit and density constraints suggested previously. This is however not to say that Option 2 is the best option in all cases involving the orangutan, or for the broader goal of ecological sustainability or biodiversity conservation. The findings here do not suggest that all intact forests should be logged and not be preserved as they are. Furthermore, it should be noted that this is a static model that does not account for subsequent logging rounds or for ecological considerations that are vital in making the type of allocative decision investigated here. It is intended to only provide a guide based on economic profitability in deciding between these two alternative logging regimes in relation to the conservation of a single species. Thus the findings here should be treated with caution and should not be applied out of context. But where heavy logging is a serious threat to the persistence of tropical forests and orangutans, the findings here could be taken as economic evidence that argues against the taking up of destructive heavy logging.

8. Discussion and Conclusion

This paper dealt with the complexities of managing a forested landscape under logging for conserving the orangutan, particularly in relation to the opportunity cost of light logging, a type of logging which appears to be compatible with maintaining orangutans in the forested landscape. This paper highlighted the economic and institutional context in which such a problem is located, a matter not sufficiently appreciated in the SFM and RIL literature, which tends to focus on the opportunity cost (e.g., Pearce et al., 2002) or technical (e.g., Putz et al., 2008) problems. It showed that the aspects of politics or power relations are significant in determining the management of a state's forests and consequently the fate of this forests' wildlife, e.g., orangutans. We saw that forestry is a declining sector in Sabah, where orangutans occur, and that a still dominant forestry department is attempting to use sustainable forest management to manage its large production forest estate that cover a vast portion of the land area of this state. The Deramakot project, as far as the published information and statistics on it go, seems to be successful in maintaining the affected forest's orangutan population while also producing profits from the sale of its logs in recent years after experiencing losses in the initial years of this project. While the SFM practiced here does take account of the ecological needs of the wildlife living in the Deramakot Forest Reserve, the long-term trajectory of orangutan densities and population sizes is not yet certain. Conducting a population viability analysis (PVA) could shed some light on this matter.

In spite of political complications (e.g., corruption), a strong bureaucracy (the Sabah Forestry Department) at the state level that seeks to preserve its relevance in the face of the decline of the forestry sector appears to have contributed to the adoption of SFM. In the case of Deramakot, SFM appears to be compatible with sustaining orangutan populations. This is even though the economics of SFM and RIL as practiced in Deramakot is not attractive in market terms compared to conventional logging. It is likely that private logging interests will not endure the risk of taking a loan to finance logging as done in Deramakot in the standard forest concessions as the returns might not justify the adoption of SFM on a large-scale by private loggers. This may be evident from within Sabah itself, where the extension of the Deramakot model has not been unequivocally successful in most of the state's sustainable forest management units (Toh and Grace, 2006). Nonetheless, it cannot be denied that some progress has been made. A government-planned approach could in some cases be more conducive to facilitating SFM. However, this might have to be balanced against the inefficiencies of bureaucracy (Niskanen, 1994) or the elite capture of the resource base through patronage politics. In decentralised Indonesian Borneo, where large timber concession areas containing substantial orangutan populations exist, a powerful central governance of the sort in Sabah no longer exists. A question worth studying at least as far as orangutan conservation is concerned is whether SFM could be seriously considered and extended across the timber production forests in Indonesia given this different institutional structure.

Finally, this paper had addressed the question often raised by conservationists regarding how forests should be partitioned for serving both economic and conservation needs. This was addressed from the economic angle. It was found here that the option of conserving the orangutan under mainly light logging is economically more attractive for a scenario involving Sabahan forests than the option of strictly protecting orangutan habitats and heavily logging forests that have no significant orangutan populations. Similar analyses are worth exploring in other locations where the orangutan exists, such as Indonesian Borneo or Sumatra, if suitable and up-to-date data could be obtained, which is likely to be a challenge. This light logging option is attractive because it is a rare example where a conservation-compatible land use can also generate employment, which is likely to be an advantage in relation to a purely PES-approach to reserving forests. The modelling performed here also assumes that forests are still worth logging. Where timbers have been removed and the potential for future prospects for the regeneration of commercial timber species is poor, industrial forest plantations may be established for continued wood production (Evans, 2009). Although this may be profitable, other social benefits such as biodiversity and orangutan conservation may be reduced. Thus earnings from non-market attributes such as carbon sequestration could supplement timber returns under light logging (Pearce et al., 2002), but markets for this are currently undeveloped. There is also the argument that sustainable logging on grounds of carbon sequestration would be used as an excuse for exploiting the remaining primary, intact or undisturbed forest landscapes (Rosoman et al., 2009). As the scale of demand for wood exceeds its dwindling supply in Malaysia and Indonesia, high levels of timber extraction, largely illegally, continue across much of Borneo (Curran et al., 2004; Nellemann et al., 2007, p. 16). In attempting to conserve the orangutan under light logging regimes and sustain these forests for the long term, these issues cannot be neglected.

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Appendix: Opportunity cost modelling for sustaining orangutans under two logging regimes: Results of sensitivity analyses

Base case					
K	Desired OU population size	=	845	individuals	
λ_P	Density on protected land	=	2	OU per sq km	
λ_L	Density on lightly logged land	=	1.5	OU per sq km	
Π_H	Profit from heavy logging	=	1121800	Ringgits per sq km	
Π_L	Profit from light logging	=	447000	Ringgits per sq km	
Change in returns (Option 2 - Option 1)		=	188857500	-	95034333.33
		=	93,823,167	Ringgits	

A. Sensitivity analysis by altering OU density

1. Protected land OU density for change in returns to be zero (indifference scenario)					
K	Desired OU population size	=	845	individuals	
λ_P	Density on protected land	=	2.49	OU per sq km	
λ_L	Density on lightly logged land	=	1.5	OU per sq km	
Π_H	Profit from heavy logging	=	1121800	Ringgits per sq km	
Π_L	Profit from light logging	=	447000	Ringgits per sq km	
Change in returns (Option 2 - Option 1)		=	151472087.7	-	151472087.7
		=	0	Ringgits	

2. Lightly logged land OU density for change in returns to be zero (indifference scenario)						
K	Desired OU population size	=	845	individuals		
λ_P	Density on protected land	=	2	OU per sq km		
λ_L	Density on lightly logged land	=	1.20	OU per sq km		
Π_H	Profit from heavy logging	=	1121800	Ringgits per sq km		
Π_L	Profit from light logging	=	447000	Ringgits per sq km		
Change in returns (Option 2 - Option 1)		=	188857500		-	188857500
		=	0	Ringgits		

B. Sensitivity analysis by altering profit

1. Heavy logging profit for change in returns to be zero (indifference scenario)						
K	Desired OU population size	=	845	individuals		
λ_P	Density on protected land	=	2	OU per sq km		
λ_L	Density on lightly logged land	=	1.5	OU per sq km		
Π_H	Profit from heavy logging	=	1788000	Ringgits per sq km		
Π_L	Profit from light logging	=	447000	Ringgits per sq km		
Change in returns (Option 2 - Option 1)		=	188857500		-	188857500
		=	0	Ringgits		

2. Light logging profit for change in returns to be zero (indifference scenario)					
K	Desired OU population size	=	845	individuals	
λ_P	Density on protected land	=	2	OU per sq km	
λ_L	Density on lightly logged land	=	1.5	OU per sq km	
Π_H	Profit from heavy logging	=	1121800	Ringgits per sq km	
Π_L	Profit from light logging	=	280450	Ringgits per sq km	
Change in returns (Option 2 - Option 1)		=	118490125	-	118490125
		=	0	Ringgits	

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