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SPECIAL FEATURE

Sustainability and biodiversity of forest ecosystems: an interdisciplinary approach

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Sustainable use of tropical forests by reduced-impact logging in Deramakot Forest Reserve, Sabah, Malaysia

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Abstract In pursuance of economic growth and development, logging has exhausted the natural timber resource in the tropical rainforest of Sabah, Malaysia. Realizing the forest depletion, the Sabah Forestry Department, with technical support from the German Agency for Technical Cooperation, begun developing a management system with the intent of managing all commercial forest reserves in a way that mimics natural processes for sustainable production of low volume, high quality, and high priced timber products in 1989. As dictated by a forest management plan based on forest zoning, about 51,000 ha of the entire area is set aside for log production and 4,000 ha for conservation in Deramakot Forest Reserve, Sabah, Malaysia. This Forest Management Plan has served as the blueprint for operational work and biodiversity conservation in Deramakot to the present. A strict protection area is set aside for biodiversity conservation within the reserve. A reduced-impact logging system is being employed for harvesting with minimal impacts on the physical environment. Deramakot Forest Reserve was certified as "well managed" by an international certification body, the Forest Stewardship Council, in 1997 and is the first natural forest reserve in Southeast Asia managed in accordance with sustainable forestry principles. In addition to providing a "green premium," certification provides easier market access, evidence of legality, multi-stakeholder participation, conservation of biodiversity and best forest management practices, particularly reduced-impact logging techniques. Deramakot Forest Reserve is the flagship of the Sabah Forestry Department and serves as a symbol of what can be achieved with political support and institutional commitment.

Keywords Deramakot Forest Reserve · Sustainable forest management · Reduced-impact logging · Tropical rain forests · Wildlife conservation

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Introduction

Certification of forest management and labeling of forest products indicates that timber is legally produced from a sustainable source. Harvesting by reduced-impact logging method is used, giving careful consideration to vegetation loss and soil erosion. Major aspects considered during forest certification are the environment (conserving biodiversity and rare species, watershed protection, erosion control), the economy (costs and benefits), and society (involvement of local communities). The forest management is assessed by an accredited third-party external auditor every 6 months to ensure the continuance of certification and compliance with sustainable forestry practices. Some indicators, such as the level of biodiversity and the population of flagship species such as the orangutan, are required to monitor forest health. For example, a stable population of orangutans indicates that the management practices are nondeleterious. It is hoped that consumers will pay a premium for this added value of the forest products and to support sustainable forest management and conservation.

As part of the permanent commercial forest estate, the Deramakot Forest Reserve (05°15′28′N, 117°20′38′E) covers 55,083 ha of mixed dipterocarp forest in the east of central Sabah, Malaysia (Fig. 1). The climate is humid equatorial with a mean annual temperature of about 26°C and is greatly influenced by the northeast monsoon (November–February) and the

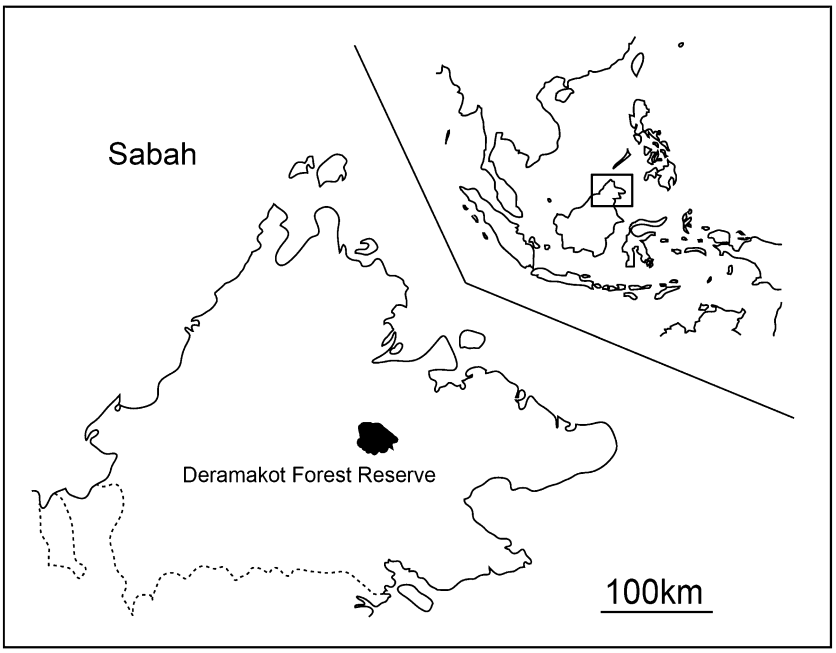

Fig. 1 Location of Deramakot Forest Reserve, Sabah, Malaysia

southwest monsoon (May–August). The average annual precipitation ranges from 1,700 to 5,100 mm (Kleine and Heuveldop 1993; Huth and Ditzer 2004).

The earliest known logging began in the southern part of the Deramakot, along the Kinabatangan River in the 1950s. The area was licensed for logging from 1955 to 1989. The minimum diameter trunk for harvesting was 60 cm and the felling cycle was 60 years. Loggers ignored the rule when it was convenient, attractive, and profitable. Variable cutting intensities of past management practices have resulted in an extremely heterogeneous condition of the remaining forest. Only 20% of the area is considered well stocked with harvestable trees, and more than 30% is covered by very poor forest with virtually no mature growing stock left.

Deramakot Forest Reserve was chosen in 1989 as the project site for the Malaysian–German Sustainable Forest Management Project for two reasons: it was the only logged natural forest that was neither licensed nor threatened by shifting cultivators, and the policy of the German Ministry of Economic Cooperation and Development prohibiting projects in pristine forests that involve timber harvesting. For the period 1989–2000, the Sabah Forestry Department, in collaboration with the German Technical Agency, implemented the Malaysian–German Sustainable Forest Management Project, which was made up of four phases: (1) a strong research emphasis with a component of management planning (1989–1992), (2) management planning, training and consolidation (1992–1994), (3) institution building, human resource and development, consolidation/implementation, and extension (1995–1998), and (4) consolidation, planning and human resource development (1999–2000). Deramakot Forest Reserve was certified as "well managed" by an international certification body, the Forest Stewardship Council (FSC), in 1997. It is the first natural forest reserve in Southeast Asia managed in accordance with sustainable forestry principles.

A medium-term (10 years; from 1995 to 2004) forest management plan for Deramakot Forest Reserve was developed over a period of 5 years (1990–1994) as part of the project and was ready for implementation in 1995 (Forestry Department of Sabah 1995). We are now entering the second forest management plan for the next 10-year planning phase, encompassing the period from 2005 to 2014 (Forestry Department of Sabah 2005). The current and previous forest management plans have served as the blueprint for operational work in Deramakot Forest Reserve to the present.

Deramakot Forest Reserve is to be managed in accordance with sustainable forest management principles and a multiple-use approach to natural forest management. Amongst other things, the plan specifies that (1) not more than 20,000 m^3 are to be harvested each year (the annual allowable cut), (2) 1,000 ha are to be silviculturally treated each year, (3) 200 ha of rehabilitation planting per annum is to be carried out on degraded sites, (4) harvesting shall follow reduced-impact logging guidelines, (5) research and development will be conducted, and (6) eco-tourism shall be part of the plan implementation.

Deramakot Forest Reserve is divided into 135 compartments of varying sizes utilizing existing roads and other natural features (rivers, streams, ridges, foothills) as boundaries (Fig. 2). The forest entity is manned by 54 field personnel deployed over six major management activities: (1) harvesting (pre-harvest planning, harvest monitoring, and post-harvest planning or closing up), (2) road construction and maintenance, (3) silviculture,

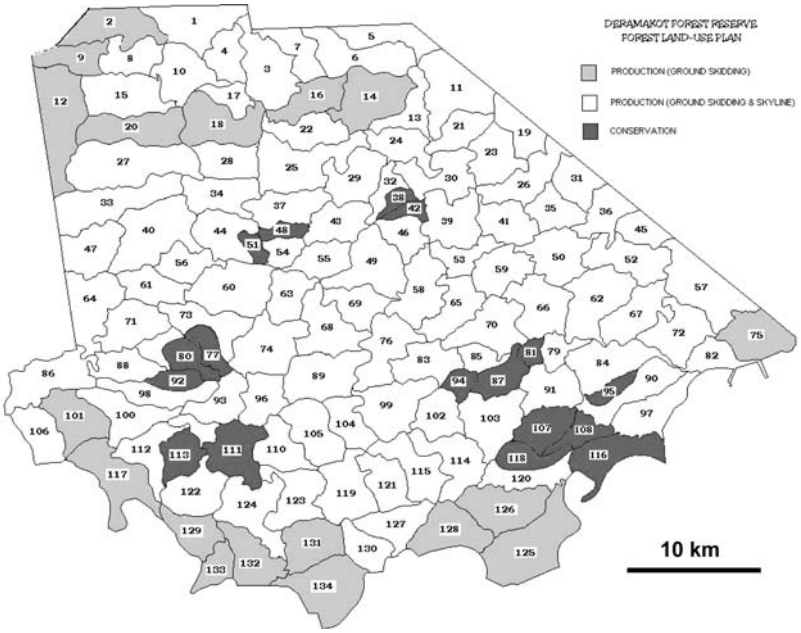

Fig. 2 Compartments of Deramakot Forest Reserve. *White* and *gray* indicate production areas. *Dark gray* indicates conservation areas

(4) rehabilitation, (5) administration, and (6) protection from illegal activity such as encroachment, hunting and forest fire.

In 1997, the Sabah Forestry Department engaged an auditing firm accredited by the Forest Stewardship Council to assess the management of Deramakot Forest Reserve under the Principles and Criteria for Forest Stewardship and the Malaysian Criteria and Indicators standard for sustainable forest management. The certification was successfully obtained covering a period of 5 years from July 1997 to July 2002. A major reassessment was carried out in Deramakot Forest Reserve by the same firm upon the expiration of the certificate in July of 2002. As a result, in April of 2003, Deramakot Forest Reserve was re-certified as a ''well-managed forest'' for a period of another 5 years from 2003 to 2008.

Forest management

The Deramakot Forest Reserve model owes its success to proper planning, concept development and to the implementation of the forest management plan. The objective is to manage the forest in a way that mimics natural processes for production of low volume, high quality and high priced timber. The main purpose of drawing up the Forest Management Plan is to define the 10-year planning objectives, which serve as guiding principles to plan ahead and operationalize the annual work plan. The main task of the Sabah Forestry Department is to prepare the annual work plan, which covers harvesting, silviculture, rehabilitation, and other forest management activities. The responsibility for supervising and monitoring all operations undertaken by the contractors lies with the Sabah Forestry Department. Both the Sabah Forestry Department and the appointed contractors are jointly responsible for carrying out these operations and ensuring compliance.

Harvesting

Sustainability of timber harvesting means harvesting not more than the annual growth. Sustainable harvesting is a measure of economic viability and a criterion for ensuring self-sufficiency and profitable returns. The annual allowable cut of 20,000 m^3 was based on the individual tree growth simulation model, Dipterocarp Forest Growth Simulation Model (Ong and Kleine 1995). However, after 5 years in operation, the mid-term review conducted in 1999 recommended that the production volume be lowered to 15,000 m^3 to ensure sustainability. Another reason was that the annual allowable cut target was never met. Table 1 compares the annual allowable cut and actual volume harvested.

Extraction of harvested logs needs to minimize the mechanical impacts on the ground. We employ ground-skidding only on slopes less than 15° and skylines on slopes from 16° to 25°.

Silviculture and rehabilitation planting

Silviculture is essential because (1) the overall stocking of desirable commercial tree species is relatively low, (2) the infestation of climbing bamboo is high, and (3) it promotes growth and assists in natural vegetation.

From 1996–2001, a total land area of 1,146 ha was planted, which corresponds to 95.5% of the targeted 1,200 ha (200 ha per year). A crucial decision was made in late 2001 to stop the rehabilitation planting and in-

Table 1 Actual production versus the annual allowable cut

Year	Compartments	Annual allowable cut (m^3)from the forest management plan	Actual volume harvested (m^3)[a]
1995	73, 60	20,000	188.61
1996	73, 60, 49, 55	20,000	15,463.40
1997	73, 60, 49, 55, 68	20,000	13,794.16
1998	73, 43	20,000	12,235.95
1999	43, 63	20,000	914.80
2000[b]	43, 29, 44, 63	15,000	12,928.43
2001	44, 34, 37	15,000	10,741.83
2002	25, 37, 33	15,000	17,196.44
2003	12, 40	15,000	15,377.22
2004	40, 56	15,000	21,634.33
2005[c]	86, 47	17,600	7,721.00
Total		145,000	93,234.39

[a] Actual volume includes rejected logs, harvesting residue and logs used for bridge construction
[b] Mid-term review
[c] As of August 2005 (compartment 86 and part of compartment 47)

Table 2 Illegal felling and forest fires in the Deramakot area, 1995–2004

Year	Illegal felling (m^3)	Forest fires (ha)
1995–1999	4,353	0
1997	–	250
2000	3,027	0
2001	214	0
2002	15	0
2003	0	0
2004	0	0
Total	7,609	250

stead to concentrate on maintaining planted seedlings for financial reasons and because of a mismatch between site and species. Those seedlings that were properly planted on suitable sites demonstrate low mortality and greater growth rates.

Protection

Protection is emphasized to ensure the security and stability of Deramakot Forest Reserve. The boundaries of Deramakot Forest Reserve, particularly those bordering alienated lands, were demarcated in 2002. Properly demarcated boundaries will facilitate enforcement work. Illegal felling has occurred over the years with the most serious occasions involving tractors. By and large this has subsided (Table 2), and if it occurs, will most probably be confined to small-time riverine felling, a form of cultural harvesting unique to the riverine communities along the Kinabatangan River.

The other threat to the forest is forest fires. The forest fires that originate from human ignitions are difficult to suppress at the best of times. In Deramakot Forest Reserve, a fire management plan is operationalized during fire season. We have an early detection and warning system (weather monitoring, fire index), prevention measures (education and awareness), and fire suppression equipment in place.

Research and development

Many scientific papers covering various fields (ecology, entomology, mammalogy, hydrology, silviculture, harvesting) have been written based on research conducted in Deramakot Forest Reserve, and many more are expected to be published in the future. Under the Eight Malaysia Plan, research on harvesting is being conducted, whereby various parameters (diameter limits, slope limitations, comprehensive harvest plan preparation, etc.) will be investigated. Deramakot Forest Reserve attracts a fair number of local students each year who conduct practical coursework prerequisites in the reserve. International researchers also visit Deramakot. Noteworthy is a team of Japanese researchers who investigated the impact of logging on biodiversity of tropical rain forests under a project of the Research Institute for Humanity and Nature. Japanese researchers in collaboration with the Sabah Forestry Department have demonstrated the efficiency of reduced-impact logging in sustaining the diversity of several taxonomic groups at the level of a pristine forest (Lee et al. 2006).

Social responsibilities

For sustainable forest management, the Forest Stewardship Council's principles and criteria address the participation of the local and indigenous people living within or on the fringes of forest reserves.

There are no indigenous people living inside Deramakot Forest Reserve, but there are six villages (20–50 households each) located on the southern fringe of Deramakot Forest Reserve along the Kinabatangan River, the longest river in Sabah. Their livelihood involves freshwater fishing; cultivating dry-paddy rice, cassava, and maize; and collecting non-wood forest products, such as rattan and medicinal plants.

A committee was set up specifically to address problems and issues of the local communities in relation to forest management in Deramakot Forest Reserve.

Meetings with representatives of the villages were conducted three times a year. Discussions primarily focused on improving the villagers' well-being so that they are able to earn a living without having to abuse the forest. Job employment as forest workers for the various forest management activities (harvesting, planting, silviculture, and boundary demarcation) in Deramakot Forest Reserve and home stay for eco-tourists were considered. Human–wildlife conflicts involving the destruction of cultivated land by elephants and other wildlife were also discussed. The welfare of the local communities, alleviating them from poverty and hardship, is the main issue, starting with supplying gravity-fed potable water (where the source is from Deramakot Forest Reserve) to one village and the creation of jobs.

Natural forest management under forest stewardship gives the greatest promise for rural jobs attuned to the cultural norms of the forest inhabitants. Silviculture, an important tool of natural forest management, suits our indigenous people and rural natives. In Deramakot Forest Reserve, 100% of silvicultural workers are natives, who earn a monthly wage. The natives from these villages are also employed in demarcating the boundary along sensitive areas of the forest.

Wildlife management

Mitigating the impacts of forest management activities on wildlife

As planned in the Forest Management Plan, approximately three-quarters of Deramakot Forest Reserve remains undisturbed or closed to forest management activities at any given time. This means all forest management activities (silviculture, enrichment planting, and harvesting) are focused on a small portion (10,000 ha) of the Deramakot Forest Reserve staggered over a period of 10 years, which translates to a management cycle of about 40–50 years. This is planned primarily to encourage plant succession without disturbance, and at the same time, the undisturbed areas act as a sanctuary for wildlife that thrives in Deramakot Forest Reserve.

Wildlife and their habitat contiguity are ensured in Deramakot Forest Reserve to ensure their sustainability. In addition, mitigating measures (Table 3) minimize the impact of human presence and interference with the ecosystem.

Wildlife conservation and monitoring

An integral part of the forest is its fauna resources. Wildlife in Deramakot Forest Reserve has received little attention in the past as the primary objective was timber management. Timber production will remain the dominant factor in planning land use in Deramakot Forest Reserve, however, to meet the requirements under principle #9 [identification of high conservation value forest (HCVF)] of the Forest Stewardship Council's principles and criteria, wildlife is increasingly gaining importance in sustainable forestry.

Two major studies on wildlife have been conducted in Deramakot. One is a population estimate of orangutans by aerial survey in 1999 (Ancrenaz et al. 2005). The other is the survey of mammal fauna at natural licks by camera trapping from 2003 until 2005 (Matsubayashi

Table 3 Mitigating the impacts of forest management activities on wildlife in Deramakot Forest Reserve

Activity	Impacts	Current management practice (mitigation)
Road construction and maintenance	Soil erosion. River/stream sedimentation. Noise	Riparian reserves are demarcated (buffers) to protect water ways. Bridges and culverts are installed to cross rivers/streams. Road width and canopy openings are minimized. Gravel is left in stream beds (for spawning). Reduced-impact logging (RIL) guidelines are strictly adhered to
Harvesting	Alteration of natural forest stand structure. Noise. Animals displaced from their natural habitat. Tree fall and shock. Loss of food supply. Habitat disturbance	Trees are marked. Directional felling is conducted. Trees that serve as seed sources, food sources and breeding niches for birds (trees > 120 cm dbh) are not felled or harvested. Roads are pre-aligned. Riparian reserves and buffer strips are maintained. Pockets of areas (> 2 ha) above 250 within the compartment are mapped and excluded from harvesting. RIL guidelines are strictly adhered to
Silviculture	Elimination of woody vines that are a food source for some animals, especially birds, and also ladders for orangutans	Removal of immediate competitors only (non-commercial trees). Maintain structural diversity to encourage natural regeneration. Avoid use of chemical defoliators
Land clearing for agriculture using fire by villagers outside the reserve along common boundaries.	Forest fire. Complete annihilation of forest	Fire management plan. Fire crews. Fire fighting equipment. Fire preparedness plan. Fire prevention plan. Fire danger rating. Community services to build awareness
Hunting	Elimination of some endangered species. Forest fires	Installation of barrier/gate at main access road. Closing all known access leading into Deramakot Forest Reserve. Surveillance and patrols

et al. 2007). The former estimated the population of orangutans in Deramakot Forest Reserve as 792 and the density as 1.5 per km^2 in 1999 (Ancrenaz et al. 2005). The latter study demonstrated the importance of natural licks for the conservation of large mammals, where 80% of the medium to large mammals of Sabah were recorded (Table 4).

The previous study clearly pointed out the importance of the conservation of medium to large mammals in production forests of Deramakot. Routine activities are being conducted in Deramakot Forest Reserve to monitor the population dynamics of wildlife. One is the orangutan aerial nest count, which is conducted twice each year and the other is opportunistic sightings (on a daily basis). The aerial counts of orangutan nests help to monitor the "health" of orangutan populations (Mannan et al. 2003). If a sudden and significant drop in the number of nests occurs, deleterious actions could have affected orangutans and these deleterious factors need to be identified immediately. Daily opportunistic sightings also help to monitor the species distribution of the various animal species.

High conservation value forest

The Forest Stewardship Council's principles require the establishment of a certain area to be protected as an HCVF. We have set aside such an area in Deramakot Forest Reserve that satisfies all criteria of an HCVF and provides a key habitat for five globally threatened large mammals, namely the orangutan, Asian elephant, banteng, proboscis monkey, and clouded leopard. Large mammals need large areas to forage, and taking measures to conserve these areas would certainly help in protecting other smaller animals that occupy the same habitat. HCVFs, as defined in this plan, are the forest entities that possess one or more of the following attributes: (1) high biodiversity values (e.g., areas of high endemism, areas known to support endangered species, areas rich in wildlife), (2) rare, threatened or endangered ecosystems, (3) representative samples of natural populations in their undisturbed form (e.g., pristine forest), (4) provision of basic nature services in critical situations (e.g., watershed protection, erosion control), and (5) areas fundamental to meeting the basic needs of local communities (e.g., subsistence, proteins, medicines,

Table 4 Medium to large mammal fauna in the Deramakot Forest Reserve

Order	Family	Species (scientific name)
Insectivora	Erinaceidae	Moon rat (*Echinosorex gymnurus*)[a]
Primates	Lorisidae	Slow loris (*Nycticebus coucang*)
	Tarsiidae	Western tarsier (*Tarsius bancanus*)
	Cercopithecidae	Red leaf monkey (*Presbytis rubicunda*)
		Silvered langur (*Presbytis cristata*)[a]
		Proboscis monkey (*Nasalis larvatus*)
		Long-tailed macaque (*Macaca fascicularis*)
		Pig-tailed macaque (*Macaca nemestrina*)[a]
	Hylobatidae	Bornean gibbon (*Hylobates muelleri*)
	Pongidae	Orangutan (*Pongo pygmaeus*)[a]
Pholidota	Manidae	Pangolin (*Manis javanica*)[a]
Rodentia	Hystricidae	Long-tailed porcupine (*Trichys fasciculata*)[a]
		Common porcupine (*Hystrix brachyuran*)[a]
		Thick-spined porcupine (*Thecurus crassispinis*)[a]
Carnivora	Ursidae	Sun bear (*Helarctos malayanus*)[a]
	Mustelidae	Yellow-throated marten (*Martes flavigula*)
		Malay badger (*Mydaus javanensis*)[a]
		Oriental small-clawed otter (*Aonyx cinerea*)[a]
	Viverridae	Malay civet (*Viverra tangalunga*)[a]
		Otter-civet (*Cynogale bennettii*)[a]
		Binturong (*Arctictis binturong*)[a]
		Masked palm civet (*Paguma larvata*)[a]
		Common palm civet (*Paradoxurus hermaphroditus*)[a]
		Banded palm civet (*Hemigalus derbyanus*)[a]
		Short-tailed mongoose (*Herpestes brachyurus*)[a]
		Collared mongoose (*Herpestes semitorquatus*)[a]
	Felidae	Clouded leopard (*Neofelis nebulosa*)[a]
		Flat-headed cat (*Felis planiceps*)
		Leopard cat (*Felis bengalensis*)[a]
Proboscidea	Elephantidae	Asian elephant (*Elephas maximus*)[a]
Artiodactyla	Suidae	Bearded pig (*Sus barbatus*)[a]
	Tragulidae	Lesser mouse-deer (*Tragulus javanicus*)[a]
		Greater mouse-deer (*Tragulus napu*)[a]
	Cervidae	Bornean yellow muntjac (*Muntiacus atherodes*)[a]
		Red muntjac (*Muntiacus muntjak*)[a]
		Sambar deer (*Cervus unicolor*)[a]
	Bovidae	Banteng (*Bos javanicus*)[a]

[a] Species recorded at natural licks

building materials, and clean water) and/or are critical to local communities' cultural integrity (e.g., areas of cultural and ecological significance).

About 4,000 ha of forests (compartments) within Deramakot Forest Reserve that are steeply dissected (with slope gradient above 25°) have been permanently set aside for protection as HCVF. However, other areas for timber production may also contain HCVF where biological and ecological values are high. Therefore, Sabah Forestry Department will conduct a review of these protection areas. At present, some natural licks are under examination for inclusion into a HCVF because of the high dependence of endangered large mammals such as orangutan, Asian elephant, and banteng on the natural licks (Matsubayashi et al. 2007).

Silviculture and rehabilitation planting improve the forest ecosystem

Silviculture seeks to eliminate weed species (climbers, creepers, bamboo, etc.) that smother and suppress regrowth of desired species. The potential crop trees of the future, by and large, are the climax species that have evolved with the wildlife. Rehabilitation planting includes tree species with large fruits that became food sources for the primates found in Deramakot Forest Reserve (including the genera *Durio*, *Dracontomelon*, and *Mangifera*). Silvicultural activities are expected to maintain the food chain and ecosystem habitats to provide the food sources that wildlife depends on and to provide habitats for frugivorous insects.

Discussion

After some 15 years (1989–2005) of intensive management in Deramakot Forest Reserve, with 8 years under certification, what are the basic lessons that we have learned to make things better and to make things happen? Let us now consider the matters and issues taken from Deramakot Forest Reserve over more than one decade of trial and error.

Without political commitment from state leaders, the concept of Deramakot Forest Reserve could not have been expanded to other areas of Sabah and manifested in the long-term Sustainable Forest Management License Agreement policy launched in September 1997. Although the Sustainable Forest Management License Agreement arrangement is still in its infancy, it is a step in the right direction and far better than the previous ad hoc timber licensing system that previously prevailed, which could cause severe damage to the forest resources.

Forest certification was found to indirectly enhance log pricing. It serves as a catalyst for amendments to the timber marketing system by sorting species into user-oriented species groups. With a sense of perspective, we therefore consider the cost of certification as fair.

Conjecture about the benefits of certification to timber producers has centered on the "market premium" and "market access" debates. The market premium for logs is defined as the difference between the price of the certified log and the price of the same log prior to the adoption of certification (Varangis et al. 1995). The issue of whether or not certified logs fetch a market premium has been discussed controversially for years (Alstair 2002). Varangis et al. (1995) estimated that in view of the market share of certified tropical timber on the US and European markets, the incremental revenue from the markets assumed to be willing to pay more for certified timber would amount to 62 million USD. Our sales of logs by auction indicate that buyers do offer premium prices for certified logs by a margin of 51 USD per cubic meter which is equivalent to a price increase of 44% as compared to uncertified logs (Mannan et al. 2002; Kollert and Lagan 2005).

Reduced-impact logging and certification are also effective in wildlife management. It has been reported that the population of endangered large mammals, including orangutan, Asian elephant, and banteng, in Sabah has suffered from habitat loss, habitat fragmentation, and habitat degradation. Our own censuses and reports from other researchers demonstrate that Deramakot sustains denser populations of these animals. We conclude that good management of Deramakot can maintain the habitat contiguity of these animals. As these animals are known as umbrella species in the ecosystem, protecting them will add momentum to conserving entire ecosystem components.

Furthermore, studies on the floristics and the soil macrofauna showed that reduced-impact logging might have left lighter logging impacts on the forests than conventional methods did. For instance, tree species diversity was equally rich in the old-growth forest and in the forest harvested by reduced-impact logging, where climax and important commercial-timber species of Dipterocarpaceae dominated, but was much lower in the forest harvested by the conventional method, where pioneer species of the genus *Macaranga* (Euphorbiaceae) dominated (Seino et al. 2006). Moreover, the size structure of canopy-tree populations showed that dipterocarp trees regenerated well in the old-growth forest and the forest harvested by reduced-impact logging. By contrast, the pioneer species demonstrated rigorous regeneration in the forest harvested by the conventional method (Seino et al. 2006). The dominance of Dipterocarpaceae was related to the community structure of soil macrofauna, and this demonstrated that reduced-impact logging was also less destructive to soil macrofauna (Hasegawa et al. 2006).

Pristine forest ecosystems consist of plant–animal interactions in addition to physical environments and organisms. To achieve truly sustainable forest management on a longer time scale, it is necessary to create a management plan that incorporates such interactions. The strict application of reduced-impact logging and the establishment of an HCVF with an appropriate

contiguity and area within a commercial forest reserve are definitely two effective measures to protect the physical environment, flora, fauna and interactions while producing timber in the reserve.

We hope that the sustainable management system of Deramakot Forest Reserve will be adopted as a model in other commercial forest reserves.

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