PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY B BIOLOGICAL SCIENCES

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Research

Changes in forest land use and management in Sabah, Malaysian Borneo, 1990–2010, with a focus on the Danum Valley region

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In an earlier special issue of this journal, Marsh & Greer summarized forest land use in Sabah at that time and gave an introduction to the Danum Valley Conservation Area. Since that assessment, during the period 1990–2010, the forests of Sabah and particularly those of the *ca* 10 000 km^2 concession managed on behalf of the State by Yayasan Sabah (the Sabah Foundation) have been subject to continual, industrial harvesting, including the premature re-logging of extensive tracts of previously only once-logged forest and large-scale conversion of natural forests to agricultural plantations. Over the same period, however, significant areas of previously unprotected pristine forest have been formally gazetted as conservation areas, while much of the forest to the north, the south and the east of the Danum Valley Conservation Area (the Ulu Segama and Malua Forest Reserves) has been given added protection and new forest restoration initiatives have been launched. This paper analyses these forest-management and land-use changes in Sabah during the period 1990–2010, with a focus on the Yayasan Sabah Forest Management Area. Important new conservation and forest restoration and rehabilitation initiatives within its borders are given particular emphasis.

Keywords: rainforest; forest management; forest rehabilitation; land-use change; selective logging; Sabah

1. INTRODUCTION

Through the 1970s, 1980s and well into the 1990s, the major agent of degradation of the lowland forests of Sabah, as in much of the South East Asian tropics, was selective logging [1]—and it was this form of disturbance, and the recovery of forests from it that has provided the focus for much of the research done as part of the Danum Valley Research and Training Programme and the Royal Society South East Asia Rainforest Research Programme (SEARRP).

By 1990, despite the intensive, industrial-scale logging of the 1970s and 1980s when extraction rates consistently exceeded 10 million m^3 a^{-1}, a significant fraction of Sabah's commercially licensed forests had been logged only once. Of the *ca* 10 000 km^2 forests managed by Yayasan Sabah, for example, which represent close to one-third of Sabah's entire commercial forest reserve, almost none had been re-logged and only relatively small areas converted to plantation. As recently as the late 1990s, the Yayasan Sabah Forest Management Area (YSFMA) still included substantial areas (at least 1500 km^2) of commercially licensed, but still primary forest.

This paper summarizes changes in forest land use and management and highlights new conservation, forest restoration and research initiatives—with particular reference to the YSFMA—that have occurred since the work by Marsh & Greer in 1992 [1]. Data and information used in this paper are derived from a wide range of unpublished and published sources and discussions with key forestry professionals in Sabah. This paper aims to provide essential background information on land-use change, policy and practices (i) as context for other articles in this special issue and (ii) for scientists and conservation managers and policymakers working in Sabah and elsewhere in South East Asia.

2. FOREST COVER IN SABAH

With a land area of 73 631 km^2, Sabah occupies just less than 10 per cent of the island of Borneo. Its population has more than doubled from 1.34 million in

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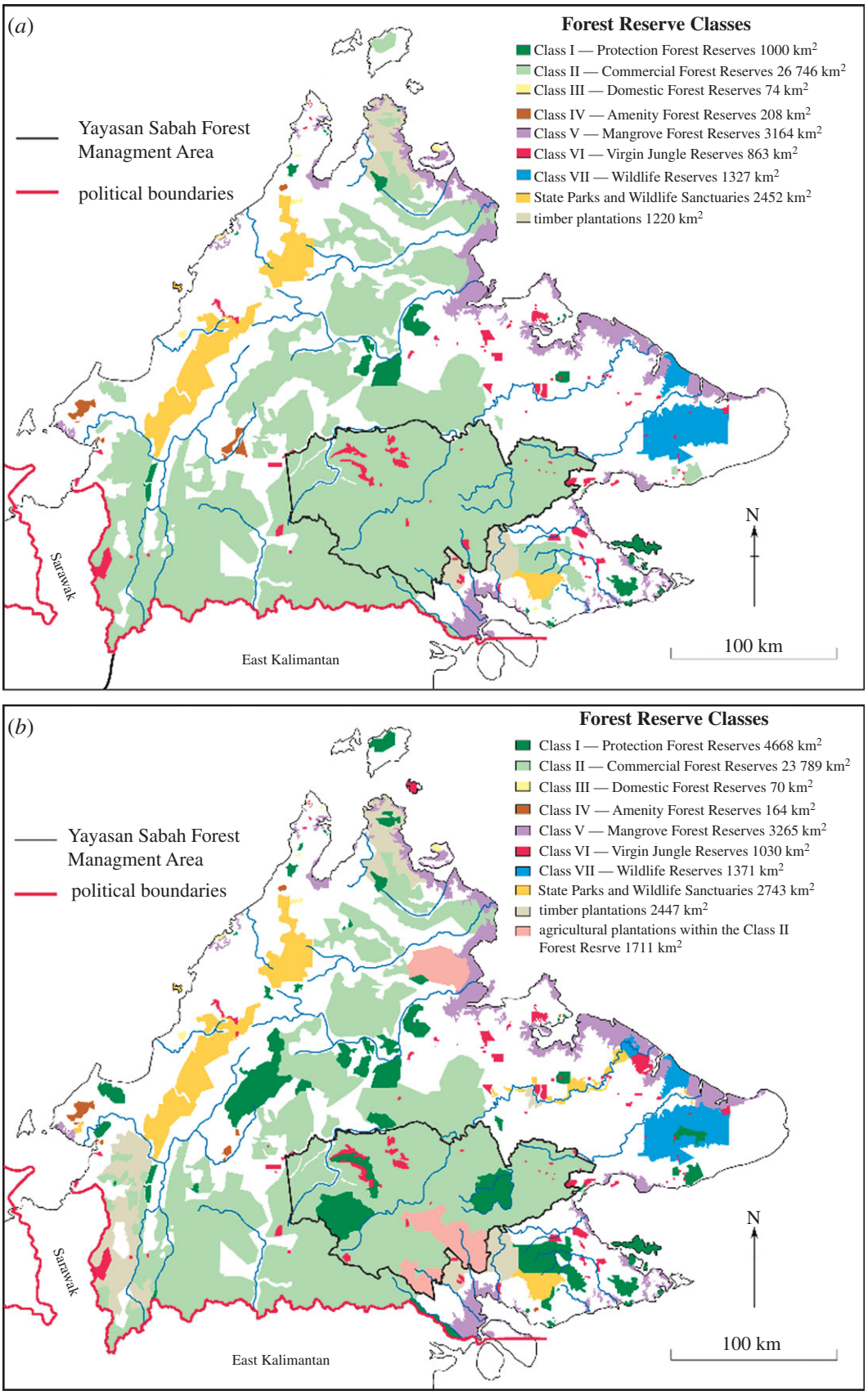

Figure 1. Forest land use in Sabah: (*a*) 1990 and (*b*) 2010.

1987 to 3.12 million in 2010 [2]. By South East Asian standards, however, population density remains low at slightly more than 40 persons per square kilometre. Furthermore, with almost half the total population of Sabah accounted for by the State's three largest conurbations, Kota Kinabalu, Tawau and Sandakan, and no major forest-dwelling communities, direct pressure on its rainforests as a source of food, fuel and building materials is much lower than in most of the rest of South East Asia.

Marsh & Greer [1] reported that overall forest cover in Sabah at the end of the 1980s (figure 1*a*) stood at

Table 1. Extent of Sabah's Forest Reserves, State Parks and other forest areas in 1990 and 2010 (adapted from Anon [3]; Sabah Forestry Department 2011, unpublished data).

forest reserve class/ forest status	1990 area (km^2)	2010 area (km^2)	change (km^2)
Class I—Protection Forest Reserves	1000	4668	+3668
Class II—Commercial Forest Reserves	26 746	23 789[a]	−2957
Class III—Domestic Forest Reserves	74	70	−4
Class IV—Amenity Forest Reserves	208	164	−44
Class V—Mangrove Forest Reserves	3164	3265	+101
Class VI—Virgin Jungle Reserves	883	1030	+147
Class VII—Wildlife Reserves	1327	1371	+44
State Parks and Wildlife Sanctuaries	2452	2743	+291
Total Forest Reserves and State Parks	*35 854*	*37 100*	*+1246*
forested state lands[b]	*ca* 8800	<500	*ca* −8300
total natural forest cover[b]	*ca* 44 654	*ca* 37 600	*ca* −7054

[a]Agricultural and other non-forest land use (1711 km^2) within the Class II Forest Reserve deducted. Total (published) area covered by the Class II Forest Reserve = 25 500 km^2
[b]Areas derived/estimated.

ca 44 750 km^2, just over 60 per cent of land area, with the bulk of this accounted for by the Permanent Forest Reserve (*ca* 33 585 km^2), which comprises seven forest use classes (table 1) and State Parks (*ca* 2450 km^2). They also noted that approaching 9000 km^2 of State lands, which at the time would have been largely forest-covered, had been alienated from the forest reserve and licensed for clearance. By 2010, few of these State lands remained under forest cover, with a large fraction having been converted to agricultural plantations (S. Mannan 2011, personal communication). Based on FAO [4] statistics, Marsh & Greer [1] estimated that the deforestation rate in Sabah for the period 1975–1985 was 1.37 per cent per annum.

By 2010 (figure 1*b*), total forest cover is estimated to have stood at *ca* 37 600 km^2 or slightly over 51 per cent of the land area.[1] This represents a reduction of *ca* 7054 km^2 since 1990 (*ca* 9% of land area and 15% of forest cover), mostly accounted for by the near-complete clearance of forest outside of the Permanent Forest Reserve and State Parks. The average deforestation rate of 0.75 per cent per annum from 1990 to 2010, however, has nearly halved when compared with the 1980s. The Permanent Forest Reserve (across its seven classes) and State Parks (parks in Sabah are established under State legislation) increased by 1849 km^2 between 1990 and 2010. This was due in large part to a near fivefold expansion in the extent of Class I (Protection) Forest Reserves from just under 1000 km^2 in 1990 to 4668 km^2 in 2010—though most of this expansion resulted from the re-classification of Class II (Commercial) Forest Reserves rather than legislation of new protected areas.

Although total forest cover in Sabah remains high by regional standards, and rates of deforestation are low, significant conservation issues remain—not least the general condition of the State's remaining lowland forests.[2] Almost all Class II (Commercial) Forest Reserves, which in 1990 had covered *ca* 26 746 km^2, have been re-logged at least once, and in some cases repeatedly, over the past 20 years, leaving extensive areas in a highly damaged condition. Despite notable initiatives towards sustainable forest management, pioneered over recent years by the Sabah Forestry Department and in the 1990s by Yayasan Sabah, there had—up to 2010—been little implementation of Reduced Impact Logging (RIL) techniques [6] and the only natural forest concession in Sabah that has been certified to Forest Stewardship Council (FSC) guidelines to date is the 55 083 ha Deramakot Forest Reserve, which is managed directly by the Sabah Forestry Department. Of particular significance, in terms of overall forest quality in Sabah, is the sharp decline in the coverage of primary lowland forest over the past 20 years. In their 1992 paper, Marsh & Greer [1] estimated that in 1990 Sabah retained *ca* 5000 km^2 of primary lowland forest, of which most lay within the Class II Forest Reserve. A significant fraction of this total, around 50 per cent, was under the management of Yayasan Sabah as part of the YSFMA. By 2010, it is estimated that less than 700 km^2 of undisturbed lowland forest remained—with almost none outside of the formally protected areas. Approximately half the total is accounted for by the 438 km^2 Danum Valley Conservation Area, which comprises mostly lowland forest, with a further *ca* 100 km^2 in the lower elevations of the Imbak Canyon and Maliau Basin Conservation Areas. Thus, close to two-thirds of the total primary lowland rainforest remaining in Sabah, some 500 km^2, is embedded within the YSFMA and under the *de facto* management of Yayasan Sabah[3]—underlining the critical importance of the YSFMA in terms of the conservation of this most important and threatened forest type.

The State Government of Sabah in 1983–1984 made a decision to allocate most lands identified in 1976[4] as of good potential for agriculture to private ownership for agricultural development, and to establish a 'permanent forest estate' of roughly 50 per cent of the State's land area (the 1990 area in table 1). Thus, the foundations were set in 1984 for the general long-term pattern of forest and agricultural land use. Within the framework provided for by this legislation, the main driver of land-use change and hence forest loss in Sabah over the past 20 years has been the demand for palm oil and the increasing profitability of its cultivation. The total area planted with oil palms increased almost fivefold from less than 3000 km^2 or 4 per cent of land area in 1990 to over 14 000 km^2 in 2010, *ca* 19 per cent of land area [7]. At least 80 per cent of land area directly replaced natural forest (authors' estimates and S. Mannan 2011, personal communication).

The increase in the extent of timber plantations over the past 20 years has been less marked. In 1990, approximately 1220 km^2 of State lands and forests alienated from the permanent reserve had been set aside for

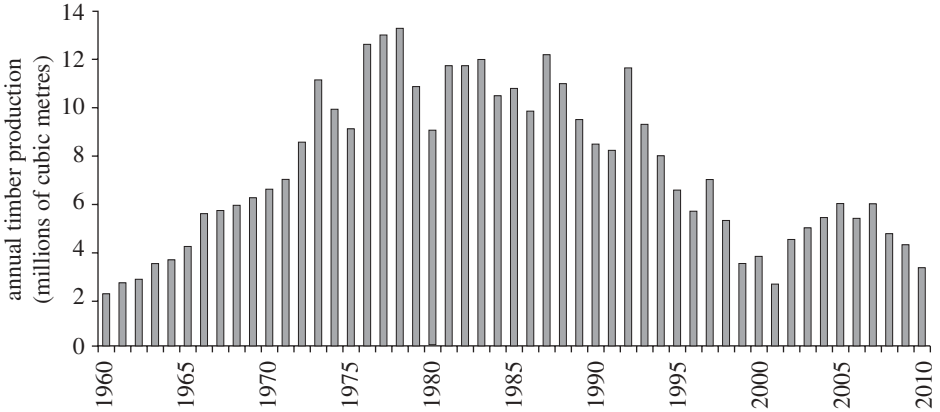

Figure 2. Annual timber production in Sabah from 1960 to 2010.

development as timber plantations, of which *ca* 400 km^2 had actually been planted (with the bulk of this area, 280 km^2, accounted for by timber plantations under the management of Yayasan Sabah's majority-owned subsidiary Sabah Softwoods Berhad). By 2010, the area nominally allocated for timber plantations had roughly doubled to 2447 km^2, of which *ca* 1290 km^2 had been planted (Sabah Forestry Department 2011, unpublished data).

Over recent years, there has been only minimal illegal encroachment of the Permanent Forest Estate. The Sabah Forestry Department estimates that less than 40 000 ha, mostly within the Class II (Commercial) Forest Reserve and scattered widely across the State, has been cleared and developed as agricultural smallholdings (S. Mannan 2011, personal communication). Although data are not available on the extent of illegal logging (i.e. felling that does not involve clearance and land-use change), this is estimated to be minimal and restricted mainly to the cutting of individual trees for immediate local use along the more accessible stretches of forest adjacent to rivers and the margins of forest reserves (S. Mannan 2011, personal communication).

(a) *Timber production*

With the industrialization of the logging industry in the decade following the Second World War, timber production from the forests of Sabah (figure 2) increased from approximately 200 000 m^3 per annum in the late 1950s and early 1960s to a peak of over 13 million m^3 in 1978. Extraction volumes remained relatively constant at 10–12 million m^3 a^{-1} through the 1970s and 1980s, though by the early 1990s, by which stage most of Sabah's richest timber stands had been heavily and in most cases repeatedly logged, production started to decline (figure 2). By 1999, the volume of timber extracted from natural forests had fallen to approximately 3.4 million m^3 a^{-1}. With the early release of logging coupes within the YSFMA and the opening of previously unworkably steep slopes through the use of helicopter yarding techniques, again within the YSFMA, this decline was temporarily arrested and for 10 years, from 2000 to 2009, timber production averaged almost 5 million m^3 a^{-1} (Sabah Forestry Department 2011, unpublished data). The bulk of this production, approaching 90 per cent in most years, came from the YSFMA (S. Mannan 2011, personal communication). However, given the degradation and limited timber stocking of most of Sabah's commercial forest reserves, and in particular the projected reduction in volume from the YSFMA, harvesting rates of this magnitude will be impossible to sustain. Sabah Forestry Department projections suggest that production will be unlikely to reach 1.5 million m^3 in 2011 and by 2013/2014 will fall to less than 500 000 m^{3}a^{-1}, at which level production is likely to remain more-or-less static for at least the next two decades (S. Mannan 2011, personal communication). In recognition of this, the Sabah Forestry Department and Yayasan Sabah, which directly manage close to two-thirds of the State's commercial forest reserves, are currently implementing large-scale silvicultural treatments, particularly climber cutting and liberation thinning, intended to improve forest structure and the eventual timber stand.

Timber plantations have played only a minimal role to date in offsetting the marked decline in production from Sabah's natural forests. Although the supply of plantation logs has increased from *ca* 189 000 m^3 in 1990 to an average of 564 000 m^{3}a^{-1} in 2000–2009 and to 670 500 m^3 in 2010, this represents only a small fraction (until very recently) of the volume harvested from the State's natural forests (Sabah Forestry Department 2011, unpublished data).

3. THE YAYASAN SABAH FOREST MANAGEMENT AREA

At over 10 000 km^2 (*ca* 1 million ha), the YSFMA (figure 3) accounts for nearly a third of total forest cover in Sabah and a similar proportion of the commercially licensed (Class II) forest reserve. Embedded within the YSFMA are three of South East Asia's largest and most important protected primary forests—the Danum Valley, Maliau Basin and Imbak Canyon Conservation Areas. The YSFMA also includes significant, and rapidly expanding, plantation interests and a number of large-scale forest restoration projects. Until the end of the 1990s, very little of the YSFMA had been logged more than once and substantial areas of primary forest in addition to the Danum Valley and Maliau Basin Conservation Areas remained.

(a) *The Ulu Segama Forest Reserve: first harvest*

As reported by Marsh & Greer [1], harvesting volumes in the YSFMA were among the highest recorded for

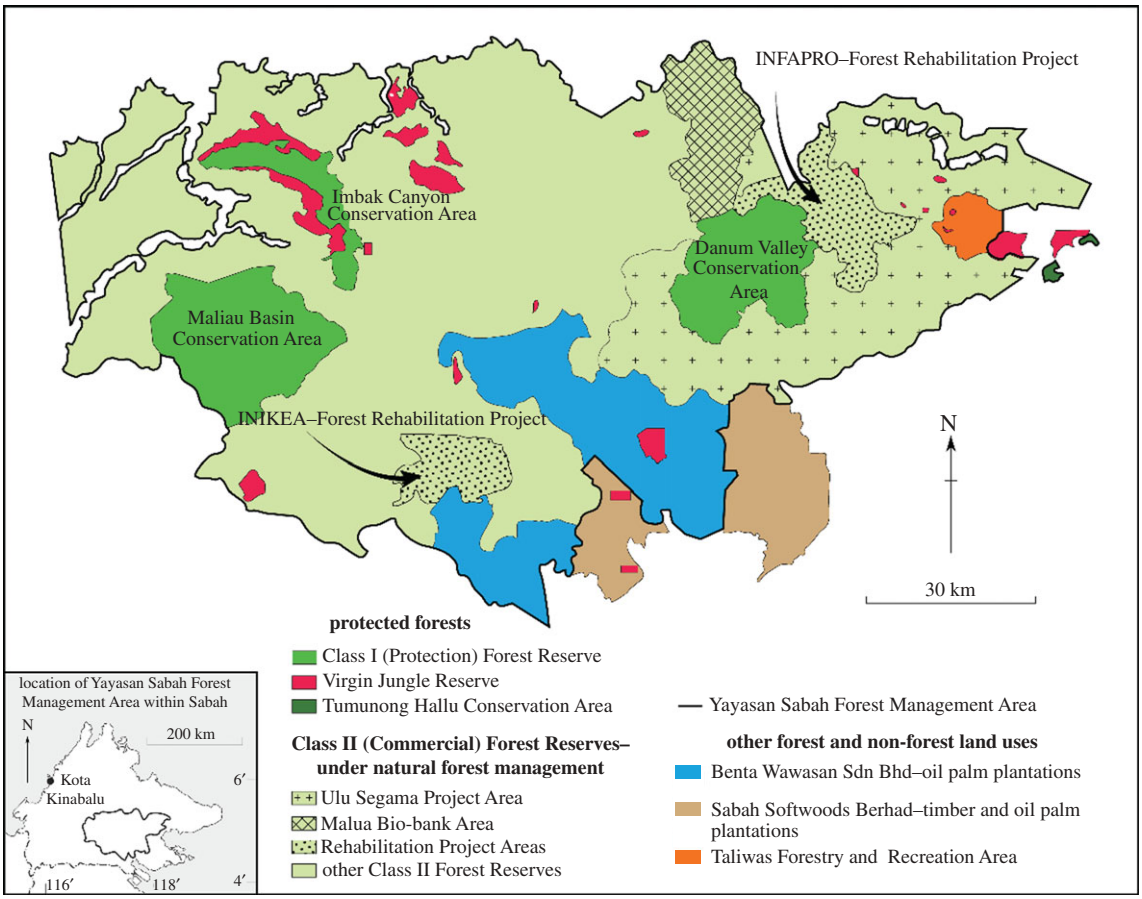

Figure 3. Forest status within the YSFMA in 2010.

any tropical forest. In the low-lying plains of the Ulu Segama Forest Reserve,[5] to the east of Danum Valley (figure 3), volumes averaged almost 120 $m^3\,ha^{-1}$ and, in the richest stands in the logging coupes surrounding the Taliwas Camp further east towards Silam, reached a maximum of close to 170 $m^3\,ha^{-1}$ (P. Moura-Costa & A. Karolus 1992, unpublished internal report). Production from the forests of the Ulu Segama and, from the mid-1990s onwards, the Kuamut Forest Reserves, was used almost exclusively to supply the Pacific Hardwoods timber mill close to the coastal town of Lahad Datu. This large integrated timber complex, which produced sawn timber, plywood, boards and mouldings, had an annual input capacity of some 280 000 m^3 and operated from 1976 until 2000, when the supply of timber from the Ulu Segama and Kuamut reserves was finally exhausted. The distances and hence costs involved in trucking the large volumes of timber required to supply the mill from the more remote parts of the YSFMA rendered its operation uneconomic, and Pacific Hardwoods was first mothballed and then closed completely in 2001.

By the mid-1990s, after almost 40 years of continual, industrial-scale logging, much of the Ulu Segama Forest Reserve had, over large areas, been considerably degraded. The pattern of disturbance of the remnant forest consisted of highly disturbed zones on the steeper slopes, especially where high-lead yarding machines had been deployed [1], along the network of skid-tracks and secondary haulage roads and in open areas created as log-landing sites and logging camps. The intervening forest mosaic, while often lacking in regeneration among the dipterocarps, was generally less damaged and, relative to most other commercial reserves outside of the YSFMA, the Ulu Segama reserve comprised some of the least degraded lowland forests in Sabah.

When timber harvesting ended in Ulu Segama in the mid-1990s, no re-logging was envisaged for at least two decades, when areas initially logged during the 1960s were due to be re-entered on the prescribed rotation of 60 years [8]. However, this rotation was not maintained and a second round of logging in Ulu Segama, along with much of the wider YSFMA, commenced in the late 1990s in response to plans for the development of an exceptionally large exotic timber plantation.

(b) *The Ulu Segama Forest Reserve: re-logging*

In 1998, Malaysia entered into a government-to-government agreement with China to develop a pulp mill with an input capacity that would have required a plantation of *ca* 2500 km^2 (net area) of fast-growing tree species in order to ensure a reliable supply of feedstock. One of the very few concession holders in Malaysia with sufficient land bank and financial resources to support such a development was Yayasan Sabah and, in the same year, a total of *ca* 3060 km^2 of forest was identified within the YSFMA for conversion, technically excised from the YSFMA and placed under licence to a subsidiary company of Yayasan Sabah, Benta Wawasan Sdn Bhd. A significant fraction of the proposed plantation—approximately 1050 km^2—fell within the Ulu Segama Forest Reserve. Development

of the plantation would have cleared this area almost entirely, along with extensive tracts of the Kalabakan and Gunong Rara Forest Reserves to the south and the southwest of Danum and westwards towards Maliau Basin.

The re-logging of the areas designated for the plantation commenced in 1999. Given that this was essentially a salvaging operation in advance of a near-complete clear fell, sustainable forest management techniques were not employed; cutting diameter limits, which had been strictly enforced at 60 cm diameter at breast height (d.b.h.) during the first cut, were reduced to 40 cm d.b.h. and the range of harvestable species expanded to include trees other than dipterocarps (which had been the main target species during the first round of logging). The harvesting rate was also greatly accelerated from 2000 to 5000 ha per annum when the Ulu Segama forests were first logged in the 1970s, 1980s and early 1990s to *ca* 20 000 ha per annum during the re-logging operation. The net harvestable area was also considerably expanded through the issuance of special licences that permitted helicopter yarding on the very steepest slopes (greater than 25°) that had been excised as unworkable when the area was first logged. Hence the mosaic of disturbed forest interspersed with areas of intact, closed canopy forest on the ridges and hill-tops, which had been a notable feature of the Ulu Segama Forest Reserve, was considerably degraded leaving it in a highly and more homogeneously damaged condition.

In terms of timber production, harvesting volumes during the second round of logging were low, averaging only 35 m^3 ha^{-1}—less than one-third of the volume per hectare removed when Ulu Segama was first cut ([9]; Yayasan Sabah 2008, unpublished data).

In 2001, plans for the pulp mill were abandoned and the agreement between Malaysia and China rescinded. Nevertheless, apparently irrevocable contracts had been awarded for the selective logging operations that would have preceded a complete clear-fell and these proceeded largely as planned—although the plantations that had been provided for under the agreement were considerably scaled-back.

The rapid re-logging of the *ca* 3060 km^2 Benta Wawasan areas rendered the planned harvesting rotations for the remainder of the natural forests under Yayasan Sabah's management largely redundant and, faced with the prospect of dwindling timber revenues, this acted as a catalyst for the early release of coupes across the wider YSFMA. By 2010, almost all the *ca* 7500 km^2 of commercially licensed natural forests of the YSFMA had been re-logged.

(c) *The Malua forest reserve*

The premature re-logging of large parts of the YSFMA included the *ca* 340 km^2 (33 969 ha) Malua Forest Reserve, which occupies a broad wedge of the forests to the north of the Danum Valley Conservation Area (figure 3). Harvesting began in 2003 and within four years all workable areas had been re-logged. However, unlike the operations in Ulu Segama, logging in Malua was not salvaging ahead of a planned conversion to plantation and, although the minimum cutting diameter was reduced to between 30 and 40 cm d.b.h. (depending on species), felling operations were generally more carefully managed under the direct control of the Sabah Forestry Department itself. With the exception of *ca* 8000 ha in the central-western part of Malua, most of the area was logged according to RIL guidelines [6] with detailed pre-felling inventories taken, target trees mapped and skid trails and haulage roads planned as part of a comprehensive harvesting plan. A maximum cutting diameter of between 120 and 150 cm d.b.h. (again, depending on species) was also introduced to protect the largest, oldest trees. Substantial areas of Malua were logged using a cable yarding system (using modified tracked excavators with a winch mounted on the hydraulic arm) designed to reduce damage to soils and residual vegetation—with helicopters used on the steepest slopes. However, despite the reduction in cutting diameter limits and the release of steep areas that would have escaped the first round of logging in the 1980s, the timber yield from Malua was low, averaging only 16 m^3 ha^{-1} (Yayasan Sabah 2008, unpublished data). This probably reflected the high intensity of the original logging operation in the 1980s and the subsequent lack of regeneration; although extraction records for the first round of logging no longer exist, it is estimated that given Malua's gently sloping terrain and relatively deep alluvial soils, the timber stand would have been rich and logging volumes concomitantly high—probably considerably in excess of even the volumes extracted from the adjacent Ulu Segama Forest Reserve. By the time harvesting operations ceased in 2007, the Malua Forest Reserve had been virtually denuded of large dipterocarps leaving a residual canopy consisting, over large areas, of near pure stands of pioneer tree species [10,11].

(d) *The Ulu Segama–Malua Forest Reserve: post-logging*

Following the abandonment of the pulp mill project and its associated plantations, the threat of immediate conversion of the Ulu Segama Forest Reserve was substantially reduced. However, premature re-logging of both the Ulu Segama Forest Reserve and the Malua Forest Reserve had left these areas, covering some 2410 km^2, in a highly degraded condition. Indeed, a 2008 Sabah Forestry Department assessment of forest quality classified 67 per cent (*ca* 1610 km^2) of the Ulu Segama–Malua complex as being 'very poor forest' with an average density of less than 10 trees per hectare with a d.b.h. greater than 40 cm [10]. Given this level of damage, and with no prospect of further timber harvesting for several decades, an incipient threat of conversion thus remained. This was, however, lifted in 2007 following an agreement between the Sabah Forestry Department, Yayasan Sabah and WWF-Malaysia that saw the Ulu Segama and Malua Reserves set aside as an area to be protected in perpetuity under natural forest cover and managed on a sustainable basis—with all harvesting operations to cease by the end of 2007. This deadline was enforced, coupes closed and the area has subsequently been promoted as a site for forest conservation, restoration and trading in ecosystem services that has already attracted significant third party funding for a variety of conservation and restoration

projects. Yayasan Sabah is also investing heavily in rehabilitation and has initiated a major, long-term silvicultural programme of release cutting involving the treatment of several thousand hectares per year.

The Ulu Segama–Malua Forest Reserve (now treated by the Sabah Forestry Department as a single reserve for management purposes) has, as of 2011, been certified to FSC standards. The Sabah Forestry Department is also proposing that a significant area, *ca* 20 000 ha to the north of the Segama River east of Danum Valley, be re-classified as a Class I Protection Forest Reserve and restored by enrichment planting (S. Mannan 2011, personal communication).

As well as assuring the future of this area, which is significant in its own right, the protection of the Ulu Segama–Malua Reserve under natural forest cover has also secured the most vulnerable eastern and northern flanks of the Danum Valley Conservation Area and the upper catchments of the Segama River and its Danum and Bole tributaries.

(e) *Plantations*

At the time of Marsh & Greer's work [1], Yayasan Sabah's only significant plantation interests were operated by its subsidiary, Sabah Softwoods Berhad. These plantations comprise *ca* 61 000 ha, separated into two blocks, in the south of the YSFMA close to Tawau (figure 3). Initially, these areas were planted with a range of fast-growing, mostly exotic timber species. Over the past decade, the range of planted species has been rationalized with the *ca* 41 000 ha eastern block mainly under *Acacia mangium* and the western block, *ca* 20 000 ha, planted mostly with oil palm. In 2010, Sabah Softwoods' *Acacia* plantations were certified to FSC standards—and at the time of writing, its oil palm plantations were being assessed for certification against the Round Table on Sustainable Oil Palm principles and criteria. In order to add value to its plantation operations, Sabah Softwoods has invested in sawmills, a chip mill and has interests in a palm oil mill, all of which are located within its estates.

Following the abandonment of the pulp mill project, the plans for a large-scale conversion to *Acacia* plantations within the YSFMA were substantially scaled back. However, given an imminent reduction in revenues from its natural forests, Yayasan Sabah made the decision to convert *ca* 106 000 ha of these forests to oil palm plantations, under the management of its subsidiary Benta Wawasan Sdn Bhd. The area to be converted, most of which lay within the Kalabakan Forest Reserve in the south-central zone of the YSFMA (figure 3), had been earmarked for conversion (at the time of industrial tree crops) as early as 1986 when the YSFMA was consolidated as a single concession [1], though until the advent of the pulp mill project these plans had remained dormant and the area concerned under natural forest cover. Special dispensation was sought from the Sabah Forestry Department for oil palms to be planted within a forest reserve and, given Yayasan Sabah's position as a para-statal organization and its social obligations, approval was granted on the basis that the areas concerned would remain part of the Permanent Forest Reserve, that only one rotation of oil palm cultivation would be permitted and that the area would eventually be returned to tree cover (S. Mannan 2011, personal communication). Clearance and planting of the area started in 2005 and the *ca* 76 000 ha (760 km^2) net plantable area is due to be fully developed by 2013.

In addition to the Sabah Softwoods and Benta Wawasan plantations, Yayasan Sabah, at the time of writing, is planning to develop timber plantations over a projected 42 000 ha in the Kalabakan Forest Reserve to the southeast of Maliau Basin. Although plans have yet to be finalized, these plantations are likely to comprise around 36 000 ha of fast-growing timber species and 6000 ha of rubber.

The combined area of the Sabah Softwoods, Benta Wawasan and Yayasan Sabah's other plantation interests, at approximately 2000 km^2 once fully developed, will ultimately comprise *ca* 20 per cent of the YSFMA including approximately 1300 km^2 under oil palm.

(f) *Protected areas*

In 1990, approximately 220 000 ha of the YSFMA, and forests physically within its borders, were due to remain unlogged [1]. These included the Danum Valley and Maliau Basin Conservation Areas, Virgin Jungle Reserves, water catchments, riparian reserves and *ca* 100 000 ha of areas excised as unworkable, i.e. areas too steep to log using conventional harvesting methods. However, only a small fraction of this total, the *ca* 30 000 ha covered by the Virgin Jungle Reserves, had any formally recognized protection status.

By 2010, the fully protected forests embedded within the borders of the YSFMA (figure 3) covered well over 150 000 ha and include three of South East Asia's most important conservation areas—Danum Valley (43 800 ha), Maliau Basin (58 840 ha) and Imbak Canyon (*ca* 30 000 ha including adjacent Virgin Jungle Reserves), which collectively account for over 130 000 ha and consist almost entirely of pristine forest.[6] As Class I (Protection) Forest Reserves, Danum Valley, Maliau Basin and Imbak Canyon have the highest level of conservation protection available in Sabah, broadly commensurate with the protection afforded to the State's Parks.

The other major change in nominally protected forests within the YSFMA over the past 20 years has been the opening of previously unworkable areas (which had previously been excised as being too steep to harvest) through the use of helicopter yarding. A significant fraction of the *ca* 100 000 ha of forest in this category has now been licensed for harvesting and, by the time of writing, much had already been logged.

In addition to the formally protected forests of the YSFMA, extensive areas have *de facto* protection from further logging, at least for the foreseeable future. These include the Innoprise-Forests Absorbing Carbon Emission (FACE) Foundation Rainforest Rehabilitation Project (INFAPRO), Innoprise-IKEA Rainforest Project (INIKEA) and Malua Bio-Bank project areas (see §3*g*), which cover a total of *ca* 75 000 ha, along with the further *ca* 20 000 ha of the Ulu Segama Forest Reserve, north of the Segama River, which is likely to be given full protection (S. Mannan 2011, personal communication).

Collectively, the total coverage of protected forests within YSFMA at the time of writing, including areas that will likely remain unlogged, stands at *ca* 250 000 ha—approximately 25 per cent of the YSFMA.

Future plans for extending and enhancing protected area coverage within the YSFMA include proposing Danum Valley, Maliau Basin and Imbak Canyon Areas as a 'cluster' of IUCN World Heritage Sites, the construction of research/environmental education centres at the Imbak Canyon Conservation Centre and a new coastal/marine site (Tamanung Hallu Conservation Area; figure 3) near to Silam and Lahad Datu.

(**g**) ***Forest restoration and rehabilitation projects***

The YSFMA includes several major, internationally co-funded forest rehabilitation and restoration projects, the INFAPRO, the INIKEA and the Maliau Bio-Bank being the largest.

Covering close to 30 000 ha, INFAPRO is the largest rehabilitation project under the management of Yayasan Sabah. It was initiated in 1992 as a joint venture between Yayasan Sabah's commercial subsidiary (Innoprise Corporation Sdn Bhd) and the FACE Foundation of The Netherlands. The INFAPRO is ostensibly a carbon-offsetting project that aims, by a combination of enrichment planting of dipterocarps by line planting and release cutting, to improve the capacity of degraded forest to sequester CO_2. The INFAPRO area acts as an important buffer to the Danum Valley Conservation Area's eastern and most accessible flank (figure 3) and comprises forest selectively logged from the late 1970s to the early 1990s. To date, approximately 12 000 ha have been treated.

The INIKEA Project, which is situated in the central-south part of the YSFMA (figure 3) and commenced in 1998, aims to restore and conserve biodiversity value in a *ca* 14 000 ha area of highly degraded forest that had been heavily logged and extensively burned during the major fires that swept Sabah in 1982/1983. This project also uses a combination of release cutting and enrichment planting—though INIKEA, unlike INFAPRO, uses mainly gap and cluster planting techniques and tends to plant trees from a wider range of genera than INFAPRO (which plants mainly dipterocarps) in order to provide a greater variety of food sources for dependent animal species. The INIKEA Project is jointly funded by Yayasan Sabah and the Swedish furniture group IKEA.

The Malua Bio-Bank (figure 3) was initiated in 2008 and aims to restore forest structure and functioning, biodiversity and to improve wildlife protection in the 33 969 ha Malua Forest Reserve. The Malua Bio-Bank uses a novel funding mechanism, the sale of biodiversity certificates, to fund its activities and is a joint initiative of the Sabah Forestry Department, Yayasan Sabah and the Australian-registered company New Forests Pty Limited. The project uses several approaches to achieve its aims including targeted forest restoration treatments (liberation thinning and enrichment planting), enhancement of wildlife habitats (construction of artificial salt licks, river crossings for orang-utan and other primates, placement of nest-boxes for hornbills, etc.), installation of manned checkpoints and increased ranger patrols in order to control poaching activities.

At the time of writing, several jointly funded restoration projects, located within the Ulu Segama Forest Reserve, were underway, including a major project in the northern Ulu Segama area to restore an important orang-utan habitat. Yayasan Sabah, also within the Ulu Segama Forest Reserve and in collaboration with the Sabah Forestry Department, has initiated and funded a major programme of release cutting, to proceed at an annual rate of *ca* 5000 ha until all the more degraded parts of the reserve have been treated, with the aim of maximizing the survival and growth of naturally regenerating dipterocarp and other tree seedlings.

4. DISCUSSION

Marsh & Greer [1] considered the omnipresent challenge to the forests of South East Asia to be selective logging, and over the two decades since their paper was published, and as demonstrated here, almost all the commercially licensed forests of Sabah, and particularly its lowland forests, have been logged to near exhaustion and by 2014 timber production from the State's natural forests will have declined by over 95 per cent from its peak in the 1970s. Much of Sabah's lowland forest is now in a highly degraded condition having been repeatedly heavily logged, with only limited use of sustainable harvesting techniques. The extensive tracts of primary lowland forest that remained intact as recently as the late 1990s have now been logged-over—though not, for the most part, converted to other land uses—and the only undisturbed lowland forests that now exist are within the network of fully protected areas. Thus, the threats which Marsh & Greer enunciated in 1992 have, in terms of the impacts of selective logging on Sabah's natural forests, largely been realized.

On the other hand, and unlike in many of its South East Asian neighbours, the overall extent of forest cover in Sabah, particularly that included in the Permanent Forest Reserve, has been largely maintained (even increased slightly) and the rate of deforestation over the past 20 years has slowed markedly compared with preceding decades. The network of totally protected forests has been greatly expanded by the formal designation of Danum Valley, Maliau Basin and Imbak Canyon Conservation Areas as Class I Forest Reserves. Several major forest rehabilitation and restoration initiatives have been launched and, of particular consequence for the integrity of the Danum Valley Conservation Area, almost all the Ulu Segama–Malua Reserve has been secured under natural forest cover in perpetuity. This represents a significant step towards maintaining the arc of natural forest from the eastern seaboard of Sabah at Silam through the lowlands of Ulu Segama and Danum Valley and onwards to the higher elevation forests of the Kuamut and Pinangah Forest Reserves and the Imbak Canyon and Maliau Basin Conservation Areas (figure 3). This *ca* 7000 km^2 swathe constitutes arguably the most important completely forest-covered area remaining on the island of Borneo and its protection, and in parts restoration, are of crucial importance.

Marsh & Greer [1] also highlighted the critical role that research stations such as the Danum Valley Field Centre play in elucidating the consequences of forest

disturbance by logging and in providing the science to underpin methods of sustainable forest management and restoration. The scientific outputs of Danum Valley and the Royal Society SEARRP over the past 25 years have made a major contribution across these fields over a range of scientific disciplines—as demonstrated in part by the coverage of papers in this special issue—and the Danum Valley Field Centre is now widely regarded as the most productive and influential field station in the Old World tropics.

Over recent years, the Royal Society SEARRP has evolved to meet the pervasive threats and challenges facing the South East Asian rainforests over the coming decades, namely (i) forest fragmentation by agricultural development, (ii) the impacts of a changing climate on forests and the biodiversity and ecosystem services they support, and (iii) the restoration of forests degraded by logging. In collaboration with its local partners, particularly Yayasan Sabah, the Sabah Forestry Department and Universiti Malaysia Sabah, and a number of leading international universities and research institutions, SEARRP has established a suite of three major projects intended to address these issues: (i) the Stability of Altered Forest Ecosystems Project [12] that focuses on forest fragmentation and ecosystem functioning and resilience within agricultural landscapes (www.safeproject.net), (ii) a 50 ha permanent plot in the primary forest at Danum Valley, to be managed as part of the Smithsonian Tropical Research Institute's global network of plots of this type (www.ctfs.si.e.du/site/Danum+Valley), and (iii) the Sabah Biodiversity Experiment [13]—a large-scale enrichment planting project that aims to examine the links between the regime of forest restoration, productivity, biodiversity and ecosystem functioning (www.sabahbiodiversityexperiment.net).

Through these strategic research initiatives and the wider scientific programmes at well-founded field stations such as those at Danum Valley and Maliau Basin, and underpinned by a progressive approach to forest conservation, sustainable management and restoration, Sabah is well placed to cement and indeed extend its position as a South East Asian hub for world-class rainforest science.

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ENDNOTES

[1]This figure is slightly less than the *ca* 38 811 km^2 total for forest cover given by the Sabah Government as we have excluded areas which, while nominally part of the permanent forest reserve, we know to have been cleared and converted to other land uses. This does not imply illegal or unauthorized clearance, rather the complexities of land-use classification. These relatively minor anomalies—covering *ca* 1711 km^2 within the Class II (Commercial) Forest Reserve—do not involve fully protected areas.

[2]Defined as forest occurring below 300 m above mean sea level [5]

[3]Technically, the Danum Valley, Maliau Basin and Imbak Canyon Conservation Areas, being Class I (Protection) Forest Reserves, are excised from the YSFMA—but are managed on a day-to-day basis by Yayasan Sabah on behalf of their respective governing committees.

[4]In the Land Capability Classification of Sabah, prepared by the UK Ministry of Overseas Development in collaboration with Government of Sabah, based largely on soil and forest surveys done in 1968–1974.

[5]The forests referred to as the Pacific Hardwoods Industrial Reserve Area (IRA) in Marsh & Greer's 1992 paper [1] were initially within the *ca* 2040 km^2 Ulu Segama Forest Reserve. The IRA was expanded in the mid-1990s to include extensive areas of the *ca* 1140 km^2 Kuamut Forest Reserve to the northwest of Danum Valley once all of the forests of Ulu Segama had been logged over.

[6]Maliau Basin and Imbak Canyon Conservation Areas include small areas of logged forest in their buffer zones. Danum Valley Conservation Area entirely comprises pristine forest.

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