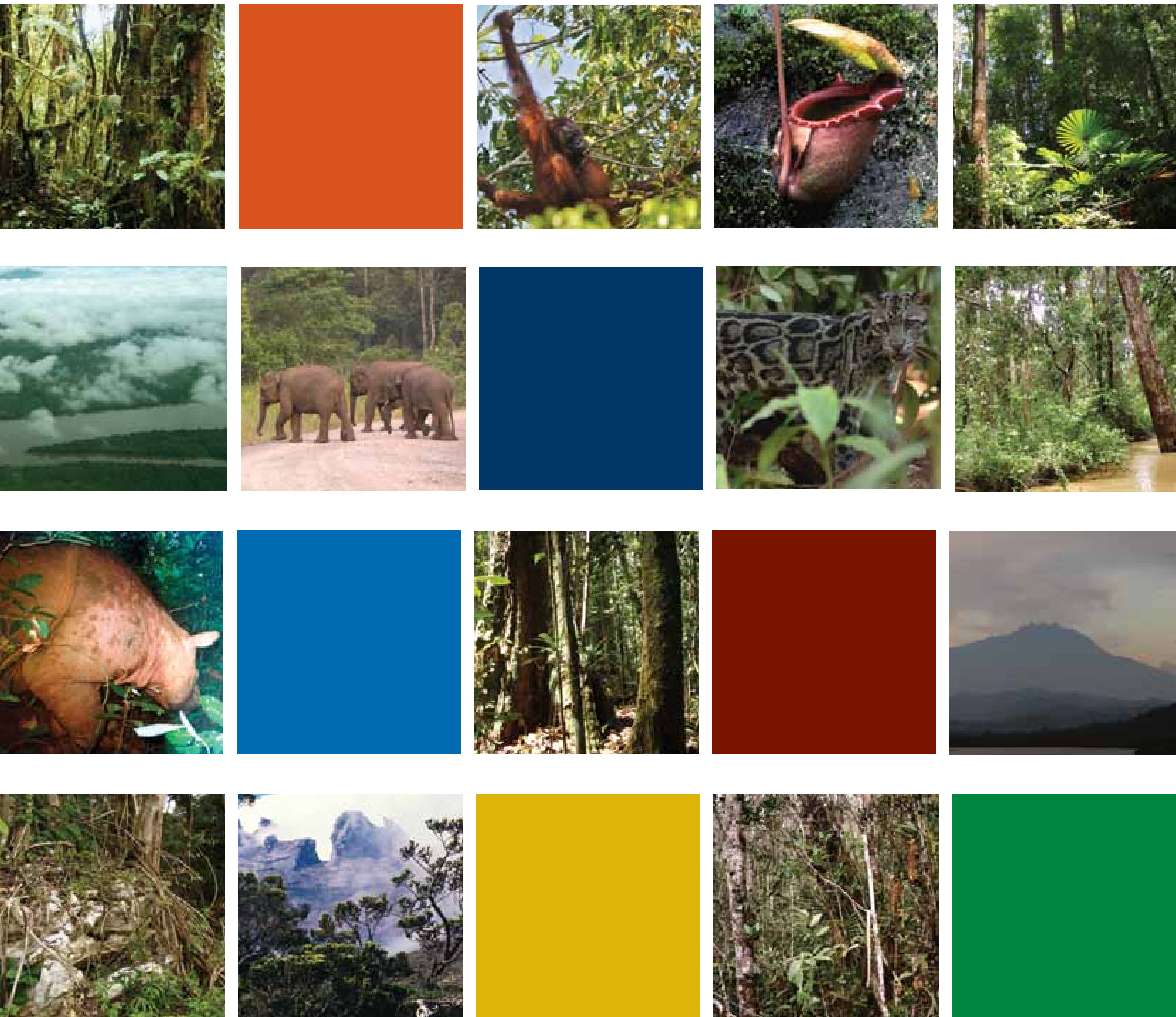
WWF REPORT HoB 2012

The Environmental Status of the Heart of Borneo



The Heart of Borneo Declaration

The governments of Brunei Darussalam, Indonesia and Malaysia signed the Heart of Borneo Declaration in February 2007. The Declaration commits the three governments to a single conservation vision to ensure the effective management of resources and conservation of a network of protected areas, productive forests and other sustainable land uses.

The initial HoB area encompassed all the interior highlands and mountains of the headwaters of the major rivers of Borneo. One of the boundaries has been expanded to include the foot slopes and important adjacent lowlands.

The major goal is to preserve the connecting forest ecosystems of the interior of Borneo by a combination of a protected area system and sustainable land use of forest resources.

The major partners in this process are the local and national governments, in particular the agencies involved in land use planning.

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WWF is one of the world's largest and most experienced independent conservation organisations, with more than five million supporters and a global network active in more than 100 countries.

WWF's mission is to stop the degradation of the planet's natural environment and to build a future in which humans live in harmony with nature, by: conserving the world's biological diversity, ensuring that the use of renewable natural resources is sustainable, and promoting the reduction of pollution and wasteful consumption.

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TOP: Landscape of the physical centre of Borneo. Photo: Stephan Wulffraat

EXECUTIVE SUMMARY

The HoB Environmental Status Project

Introduction

Despite all the global attention, until now no comprehensive data has been presented about the current state of the natural systems in the Heart of Borneo (HoB). Until recently, no-one had asked questions about this globally important region such as:

> How much tropical rainforest remains in the HoB? Is it viable for the long term?

> What are the top three threats in the HoB? What is that estimation based on?

> How much peat forest is currently in protected areas in the HoB? Is that enough?

This report attempts to provide this data.

Measuring the vital signs

Beginning with a small group of experts on the natural history of Borneo, a set of 13 indicators was chosen to represent the dominant and critical ecosystems and species on the island (see Appendix 1).

Once a consensus was reached on the indicators, remote sensing and geographic information specialists set out to collect meaningful data for each one. If the data for a particular indicator was considered insufficient or unrepresentative, it was put on hold until better methods or data become available.

The Project objectives

The goal of WWF's HoB program participation in the pilot was the "development of a practical measures framework and data status for biological and socio-economic outcomes of conservation and community empowerment field activities."

There were three specific objectives:

1. Identification of parameters/indicators for measuring the biological and socio-economic status in the HoB.
2. Preparation of the comprehensive and updated set of status data needed for measuring the indicators.
3. Application of the full social aspects of the Conservation Measures framework as field trials in two existing WWF-Indonesia work sites in the HoB, including Kayan Mentarang and Betung Kerihun National parks (this objective will be discussed elsewhere).

A unique set of criteria was developed so that each indicator could be rated Very Good, Good, Fair or Poor in a meaningful way. By combining the indicators, statements can be made about particular components of the HoB's natural systems or about the HoB as a whole.

We need to know more about several indicators; we hope practical methods and resources will emerge to capture that data. Overall, enough information has been collected to make some broad statements about the vital signs of the HoB. These metrics will improve in the next few years.

Threats to the HoB

Looking forward 10 years, the top threats are:

> industrial conversion of natural forests

> illegal logging

> legal commercial but unsustainable rates of timber extraction

> forest fire

> mining

> over-hunting and collecting.

Because of the relatively short future window (10 years) climate change was not classified as one of the top threats. But an increase in climatic variability may exacerbate some of the other threats. Only two of the prioritised direct threats are currently amenable to data collection using remotely sensed data: industrial conversion and forest fires. There are no annual analyses of industrial conversion. Forest fire data were compiled for a 14-year period – locations were marked but no real information of annual forest fire loss was quantified in terms of carbon losses.

Conservation management

The primary conservation management indicator is the extent to which different natural ecosystems are covered by legally protected areas. Ten per cent of each natural ecosystem is a globally agreed minimum. For the Heart of Borneo, 20% (of the remaining ecosystem) is a more reasonable goal. Conservation science indicates that larger percentages are more likely to support biodiversity and buffer against changing climate.

Another important component for conservation management is the extent to which protected areas are effectively performing their role. A comprehensive survey of the management of the HoB's protected areas has yet to be carried out – but would be a very high priority.

The definition of what constitutes a protected area is contentious. In Sabah, for example, Dermakot and Ulu Segama Forest Reserves are not considered protected areas, although they are managed for sustainable wood production, and forest restoration programs are in place for damaged areas within these Reserves. Together, they harbour the largest orang-utan population in Malaysia (J. Payne, pers. comm.).

Implications

The ecological systems are broadly doing well, with some exceptions. The pressure on the remaining HoB forests and associated species has never been greater. Though precise data is not often available, as forest areas continue to shrink and experience fragmentation, the pace of conversion and degradation can increase, and increasing climate variability combined with fire can be devastating.

The largest ranking threat to the integrity of the HoB is industrial conversion of natural forests. Conversion is mainly occurring to establish oil palm plantations and smaller areas for pulp wood plantations. The ecosystem mostly affected is the lowland rainforest. Most locations are at the edges of the HoB, as defined by WWF though some inland areas in West Kalimantan are also allocated.

Forest fires are also considered a major threat. These devastating events have occurred mainly at the edges of the HoB and the main ecosystems affected are heath forests, lowland rainforests and peat swamp forests.

Mining is a threat that has been somewhat underestimated so far, probably because of lack of data. The major type of mining in the HoB is for coal, which is always done by digging in open pit mining. Mining concession data is not officially available and to complicate analysis even more, there are many small concessions holders, less inclined to environmental protection, that get sub-concessions from the larger companies. Mining often occurs at interior foot slopes of mountains of the HoB, particularly in Central Kalimantan.

Protected area coverage in the HoB's main ecosystems

Ecosystem	Area protected	% protected
Lowland rainforest	3,355 km^2	9.6%
Upland rainforest	13,177 km^2	18%
Montane forest	9,959 km^2	29%
Heath forest	<300 km^2	<1%
Limestone forest	<200 km^2	<1%
Peat swamp forest	<1%	0%

Future developments

The good news is that the governments of the HoB have pledged to protect and restore the natural gifts of the HoB for the benefit of local, national, and even global constituencies.

Their bold commitments, supported by non-governmental organisations, provide great promise that a balanced configuration of land use will eventually protect and maintain natural systems in the HoB and the ecosystem services that they provide.

This report will be used internally by the WWF network to monitor progress of the HoB Initiative in terms of improvements in key biological measures for the Heart of Borneo.

With appropriate funding, future editions of this report will include biological indicators in increasing number and diversity, leading to a broader and increasingly accurate representation of the flora and fauna of the HoB.

A number of current HoB projects, such as the expedition to discover and document wildlife in the Sungai Ingei Protection Forest in Brunei's portion of the Heart of Borneo, will provide added information to further improve the use and accuracy of this document.

This report will also serve as a bell-wether on progress towards the delivery of WWF's conservation goals for the HoB. It is hoped that the three HoB governments will also find the report useful as they plan the conservation and sustainable development of the 22 million hectares of the interconnected, biodiversity-rich forest that the Heart of Borneo represents.

Key ecosystem or species
Lowland rainforest
Upland rainforest
Montane forest
Peat swamp forest
Limestone forest
Heath forest
River ecosystems
Bornean elephants and banteng
Sumatran rhinoceros
Bornean clouded leopards
Orang-utans
Bearded pigs
Endemic pitcher plants

Key HoB indicators

The results for the natural system indicators for which there was sufficient data are summarised in the table below. When combined, these individual indicator ratings result in an overall rating of Good for the HoB. That is encouraging, though the picture is mixed and each indicator tells a story that is worth reading. It should be noted that the discussion of ecosystem viability is restricted to the HoB only – not the entire island of Borneo.

Lowland rainforest

The project produced an updated map of the extent of lowland rainforest ecosystems. The HoB boundaries were drawn to incorporate adjacent, contiguous lowland rainforest, so the 63% of remaining historic lowland rainforest (classified as Good) is a bit misleading. Island-wide, lowland rainforest is quickly becoming rare, due to logging and forest fires. Elephants and orang-utans live in lowland rainforest almost entirely below 150 m asl.

Upland rainforest

The picture looks brighter for upland rainforest ecosystems, the major HoB ecosystem. Most (82%) are still standing and in many cases in primary condition, giving a Very Good rating.

Montane forest

Nearly all of Borneo's montane forest ecosystems are within the HoB, and the 89% of remaining historic montane forests are generally still in primary condition, resulting in a Very Good rating. These areas have a very high rate of local endemism (unique to a defined geographic location) for animal and plant species.

Peat swamp forest

Peat swamp ecosystems occur mainly in the wide coastal lowlands. Many of those areas have either been converted or are highly disturbed. Interior peat swamp areas within the HoB are generally in better condition, and 72% of historic peat swamp is still present, resulting in a viable rating of Good. However, we have to keep in mind that most of these forests have been logged.

Limestone forest

Limestone ecosystems are scattered throughout Borneo, but the only large areas are at the Sangkuliran peninsula in East Kalimantan and northern South Kalimantan. These are partly degraded while the smaller limestone areas in the interior are all in relatively healthy condition. Degradation of limestone ecosystems is usually irreversible. The extent of limestone forest is above the proposed viable threshold of 60% of historic extent and is rated as Good.

Key ecosystem or species	Indicator	Raw data	Result	2008 rating
Lowland rainforest	% of historical extent	58,897 km^2	63%	**Good**
Upland rainforest	% of historical extent	89,879 km^2	82%	**Very Good**
Montane forest	% of historical extent	38,511 km^2	89%	**Very Good**
Peat swamp forest	% of historical extent	6,572 km^2	72%	**Good**
Limestone forest	% of historical extent	386 km^2	79%	**Good**
Heath forest	% of historical extent	4,285 km^2	48%	**Fair**
River ecosystems	% natural cover in Kapuas watershed	39,230 km^2	47% overall	**Fair**
	% natural cover in Barito watershed	38,020 km^2	63% overall	**Good**
	% natural cover in Mahakam watershed	41,130 km^2	54% overall	**Fair**
	% natural cover in Kayan watershed	28,280 km^2	95% overall	**Very Good**
Bornean elephants	Total population	~1,000 individuals	~1,000 individuals	**Fair**
	% of historic distribution	22,000 km^2	~60%	**Good**
Sumatran rhinoceros	Total population	<50 individuals	<50 individuals	**Poor**
Bornean clouded leopards	Suitable habitats for viable populations	165,170 km^2	76%	**Good**
Orang-utans	Average densities in peat swamp and lowland forests	0.61 and 0.48 individuals/km^2		**Fair**
Endemic pitcher plants	% of viable historic locations	21	80%	**Good**

The 2008 rating is an indicator but methods of mapping forest conditions are still being investigated/developed.

Heath forest

Originally, there were large stretches of heath forest, particularly in Indonesian Borneo. Few wide areas are left, and these are mainly in central and east Kalimantan. Even these are not in pristine condition, as several areas have been burned in the past 25 years. Due to the poor soils that heath forest develops on, their restoration is extremely difficult. Existing heath forest is 48% of historic levels compared with the proposed viable extent of about 60%, giving a Fair rating.

River ecosystems

There is little information about the in-stream biodiversity status of Borneo's rivers. The most practical indicator considers the percentage of forest cover in the watershed of each of the main rivers. Southern and western Borneo are generally converted, while conditions in the north are somewhat better. The overall HoB rating for this indicator is Fair. A more comprehensive picture of freshwater biodiversity must be seen as a priority.

Bornean elephants and bantengs

Due to their similar ecological roles and use of habitat, elephants and banteng were grouped into one conservation target – forest-edge herbivores – but little is available about bantengs. Elephants, which are mostly in Sabah, have suffered as a result of habitat conversion. Population size, distribution and connectivity will be the major indicators to measure. The total population remains relatively stable, as elephant herds move from destroyed habitats into protected habitats. The proposed desired rating for population size is only Fair (seen as the best long-term scenario, requiring constant management).

Sumatran rhinoceros

The only locations where there is still an opportunity for Borneo rhinoceros to survive are in a few protected areas in Sabah, partly outside the HoB. The occasional records from other areas most likely refer only to single individuals and no viable populations. WWF in Sabah keeps records of all rhino sightings and is compiling updated documentation. The proposed desired future rating for rhinoceros is only Fair (the best long-term scenario, requiring constant management).

Bornean clouded leopards

The clouded leopard is one of the top predators and the largest cat species of the island. It is likely to play a major role in regulating healthy populations of monkeys, ungulates and smaller mammals. A viable population of at least 50 individuals needs an estimated 400 km^2 of uninterrupted forest blocks. The rating for viable populations is a good indicator of connectivity of large connecting blocks of forests. There is currently minimal data on the clouded leopard in Borneo, but based on available habitat, it is possible the conservative rating for the population is Fair to Good.

Orang-utans

Most orang-utan populations of Borneo live outside the HoB boundaries. However the HoB also harbours a number of large populations, mainly in its lowland and peat swamp forests in West and Central Kalimantan and in Sabah. The populations in the HoB are relatively stable, because most are in protected areas. However, many populations in the other parts of Borneo are under severe pressure. The densities in lowland as well as in peat swamp forests of the HoB are rated Fair. The long-term scenario is to improve the rating for peat swamp forests to Good through the many conservation efforts in the Danau Sentarum and corridor to Betung Kerihun area. Good chances of orang-utan conservation success can also be achieved in remote hilly lowland areas where orang-utans can now be reintroduced.

Endemic pitcher plants

Endangered plant species are represented by the rare endemic pitcher plants (Nepenthaceae), for which distribution records exist for most species. These pitcher plants serve as a good indicator species as they grow mainly in fragile habitats. Several species are restricted to mountain summits in Sabah, which are all State parks. A number of species occur only in locations without any legal protection status. The relatively high level of attention to these rare species provides some form of protection. The estimated rating is Good.

Introduction

Background

This document is an attempt to summarise the current state of the environment of the Heart of Borneo (HoB). It discusses the methods, collected data and selection of appropriate indicators while analysing the data, and presents the resulting conclusions.

This information will be the baseline for the long-term monitoring program to regularly assess the HoB's status. Suggestions from readers will be incorporated in further development of the measures framework.

The assessment of the HoB's environmental status was initiated through the WWF Conservation Measures program. This is a two-year pilot effort to measure the status of several WWF priority places. The four-component Conservation Measures framework generates baseline information that can be used to measure the long-term effectiveness of conservation strategies critical to effective conservation planning across large geographies.

The four components are:

> biological targets

> threats

> conservation management

> social well-being.

This document focuses on the first three components, which directly contribute to this status, with emphasis on obtaining existing data rather than primary data collection. Indicator-specific rating criteria were developed, especially for biological parameters, to allow the state of any indicator to be evaluated relative to long-term viability of an ecosystem or species.

The program was a collaborative effort to identify indicators in each of the four categories, and then collect, map and analyse data to depict baseline (current) conditions in each place.

Staff from WWF-US Conservation Science Program provided guidance and technical assistance to program staff in each of six geographies. The work was done by a Measures Officer(s) in each geography. These individuals or teams scoured sources of existing data, compiled and analysed the data and created maps to display the current status of many indicators across their geography.

TOP: Riparian forest along a stream in Central Kalimantan. Photo: Stephan Wulffraat

Heart of Borneo

The island of Borneo – the third largest on Earth – represents one of the planet's most biologically diverse collection of ecosystems (MacKinnon et al, 1996). The highly varied topography has led to a rich variety of forest ecosystems, from swamp and dipterocarp forests in the lowlands to upper montane cloud forests in the mountains. An extremely high number of plant and animal species have evolved in these forest ecosystems, many endemic to Borneo. While some lowland areas have been converted to other land uses, much of the interior is intact.

This interior – the Heart of Borneo – covers the upstream sections of the island's major river drainage areas. The tropical rainforests cover almost 30% of the island and form one of the largest contiguous forests remaining in South-East Asia. Most of the original forest ecosystems and wildlife are still present and the preservation of this region is being given the highest conservation priority by WWF.

In February 2007, with the signing of the HoB initiative, the governments of Indonesia, Malaysia and Brunei committed to protecting the HoB and promoting sustainable use of its resources. WWF's HoB Program is one of WWF's global focal points, known as a Network Initiative, and is hosted by WWF-Indonesia.

The HoB is also known for the cultural and linguistic diversity of the indigenous peoples, collectively known as Dayak. Local people depend on the forest for a variety of resources, including wood, food, medicinal plants, non-timber forest products for trade, wild game, fish, construction materials and water. The traditional management practices of the Dayak communities have contributed to sustainable management of natural resources of the area over the centuries, though in some cases misunderstandings have lead to the local extinction of certain species such as rhinos and straw-headed bulbuls.

Conservation measures

Though the global Conservation Measures program ended in February 2009, the HoB program is continuing. This document is an effort to summarise the work to date, and solicit input on refinements and next steps.

Objectives

The goal of WWF's HoB program participation was the "development of a practical measures framework and data status for biological and socio-economic outcomes of conservation and community empowerment field activities."

There were three specific objectives:

1. Identification of parameters/indicators for measuring the biological and socio-economic status in the HoB.
2. Preparation of the comprehensive and updated set of status data needed for measuring the indicators.
3. Application of the full social aspects of the Conservation Measures framework as field trials in two WWF-Indonesia work sites, Kayan Mentarang and Betung Kerihun National parks.

Identifying HoB Status Indicators

A meeting to identify status measures was held in November 2007 at WWF-US in Washington, DC. The main participants had a long history of working in Borneo and a holistic view of Borneo's biodiversity and/or threats.

The process for identifying indicators was based on the Open Standards for the Practice of Conservation (Conservation Measures Partnership, 2007). The monitoring framework is an elaboration and modification of an existing framework (Parrish, Braun & Unnasch, 2003, Gordon et al, 2005), which is a subset of a method for conservation planning, developed over the course of 20 years (Poiani et al, 1998).

Key activities included:

1. Identification of a small set of **biological targets** – ecosystems and species that are representative of the key ecological systems and processes for the HoB.
2. Identification of **key ecological attributes** for the conservation targets.
3. Identification of quantifiable **biological indicators** for each key ecological attribute.
4. Identification of the **major threats** to HoB biodiversity.
5. Rating of each threat/biological target combination to develop an overall; (expert-driven) threat assessment allowing for an **overall threat ranking**.
6. Identification of specific **threat indicators** based on the overall threat rating.
7. Identification of **conservation management indicators** that would allow the tracking of human management systems intended to conserve biodiversity.

Thirteen biodiversity targets (Activity 1) were selected that were a combination of Borneo's major ecosystems and key species:

> lowland rainforest ecosystems

> upland rainforest ecosystems

> montane forest ecosystems

> peat swamp forest ecosystems

> limestone forest ecosystems

> heath forest ecosystems

> river ecosystems

> forest edge herbivores – Bornean elephants (*Elephas maximus*) and banteng (*Bos javanicus lowi*)

> Sumatran rhinoceros (*Dicerorhinus sumatrensis harrissoni*)

> Bornean clouded leopard (*Neofelis diardi*)

> orang-utans (*Pongo pygmaeus*)

> bearded pigs (*Sus barbatus barbatus)*

> Nepenthaceae pitcher plants (representing endangered plant species).

Key ecological attributes, indicators, and indicator rationale (Activity 2 & 3) were developed for the biological targets and are summarised in Appendix 1.

A comprehensive list of threats was developed for the HoB. Each threat was linked to the appropriate biological target in a conceptual model (Appendix 2) (Activity 4 & 5). Each pair was rated for severity, scope and irreversibility. These results were combined (Appendix 3).

Based on the overall threat ranking, quantifiable indicators (Activity 6) were developed for the highest ranked threats developed from the previous step. These were:

> industrial conversion of natural forests

> illegal logging

> legal commercial but unsustainable rates of timber extraction

> forest fire

> mining

> over-hunting and collecting.

The threat indicators and rationale are summarised in Appendix 1.

Several conservation management indicators (Activity 7) were chosen, generally associated with protected areas and protected area management.

Developing indicator-specific viability criteria

The next step was to develop indicator-specific rating criteria based on a set of generic viability criteria:

> Very Good – Ecologically desirable status; requires little intervention for maintenance

> Good – Within acceptable range of variation; some intervention required for maintenance

> Fair – Outside acceptable range of variation; requires human intervention

> Poor – Restoration increasingly difficult; may result in extirpation of target.

Indicator-specific thresholds will improve over time, as more information on ecologically desired status and acceptable range of variation is identified. Appendix 1 lists the long-term viability (generally the 'Good' rating level) goals where they have been developed.

Collecting and analysing data

Data was collected from March to October 2008 for Indonesia, and from June to August 2008 for Malaysia. In mid-August 2008, the teams from both countries gathered in Jakarta for a review of data collection progress and results.

Obtaining data from reliable existing sources was relatively straightforward for the biological indicators. Sources included remote sensing data, WWF projects, program partners and/or consultants. Many of the indicators are in the form of spatial information, with additional field information. The compilation and analysis of the status data for the ecosystems indicators was facilitated by an up-to-date cloud-free satellite image mosaic for the whole of Borneo (250 m resolution MODIS satellite image mosaic, SarVision 2008).

Data collection for the biological, threat and conservation management indicators was largely undertaken by WWF-Indonesia staff. WWF-Malaysia engaged an external consultant for data collection in Sarawak.

Some primary data was collected under the auspices of other pre-existing WWF programs. Several surveys of river ecosystems, peat swamp ecosystems and lowland rainforest remnants were conducted in East and Central Kalimantan to identify High Conservation Value Forests to be preserved in oil palm plantation developments. Surveys of lowland ecosystems were carried out in Central and West Kalimantan, mainly to identify suitable habitats for orang-utan conservation. These activities served to fill in information gaps for the biological indicators.

Data and preliminary analyses were compiled in Jakarta during July-August 2008. More intensive meetings of members of the WWF-Indonesia Conservation Measures team were held throughout 2008 and 2009.

Evaluating protected area management effectiveness

Protected area management effectiveness (PAME) is the term used for "the assessment of how well the protected area is being managed – primarily the extent to which it is protecting values and achieving goals and objectives" (Hockings et al, 2006).

There are three main elements to the management effectiveness of protected areas:

> design issues relating to both individual sites and protected area systems;

> adequacy and appropriateness of management systems and processes; and

> delivery of protected area objectives including conservation of values.

The PAME indicator forms part of the 2010 Biodiversity Indicators Partnership. This partnership is a CBD-mandated initiative bringing together a suite of biodiversity indicators, allowing for a more comprehensive and consistent monitoring and assessment of global biodiversity, with a view to measuring progress towards the CBD's target to reduce the rate of biodiversity loss by 2010.

There are a number of methods that can be used to evaluate PAME. When considering which to use, the first issue that must be addressed is whether one wants to evaluate a single protected area or a (national or provincial) protected area network. For single protected areas, the most widely applied tool is the Management Effectiveness Tracking Tool (METT, Stolton et al, 2007). For protected area systems (or individual protected areas), the Rapid Assessment and Prioritization of Protected Area Management (RAPPAM) tool (Ervin 2003) is the most familiar. The emphasis of the current scoring tools is on the inputs and outputs of resource management more than the actual status of the resources within protected areas.

Evaluation of protected area management effectiveness will be conducted in all National Parks of Kalimantan.

The RAPPAM questionnaire considers the following elements of protected areas:

1. Background information
2. Pressures and threats
3. Biological importance
4. Socioeconomic importance
5. Vulnerability
6. Planning objectives
7. Legal security
8. Site design and planning
9. Staffing inputs
10. Communication and information
11. Infrastructure inputs
12. Finance inputs
13. Management planning processes
14. Management decision making processes
15. Research, monitoring, and evaluation processes
16. Outputs

Links

World Database of Protected Areas http://www.wdpa.org/ME/Default.aspx

METT http://assets.panda.org/downloads/mett2_final_version_july_2007.pdf

RAPPAM http://www.panda.org/parkassessment;

– John Morrison

RAPPAM participants discussing the questionnaire.
Photo: © Ministry of Forestry/ Erwin Soegandi

Data summary

This section describes the findings from the data collection and analysis effort.

Biological Status

Appendix 1 lists the indicators identified to characterise the biological status of the HoB. Arguably, the most important indicator for each ecosystem is the simple extent of remaining habitat (also expressed as % of historic extent). Fortunately, a previously contracted composite remote sensing image was available for analysis (SarVision 2008). This allowed comparison of the historic extent with a recently developed remote sensing image depicting current forest cover using a geographic information system (GIS).

The initial historic and current extents of each ecosystem type were developed from a variety of sources, described in Table 1.

The 250 m resolution of the available satellite imagery did not allow analysis of the condition within forest patches or identification of the presence of key species. Table 2 shows the results of the remaining forest cover analysis, including the 'proposed desired %', which represents the consensus from the November 2007 meeting.

It should be noted that this discussion of ecosystem viability is restricted to the HoB only – not the entire island of Borneo.

Historical and current extents

Lowland rainforest ecosystems (page 38)

The HoB boundaries were drawn to incorporate adjacent, contiguous lowland rainforest, so 63% of the remaining historic lowland rainforest is within the HoB (classified as Good). Island-wide, little lowland rainforest is left, due to logging and forest fires and is becoming rare.

Upland rainforest ecosystems (page 42)

The picture looks a bit brighter for upland rainforest ecosystems, the major ecosystem of the HoB. Most (82%) are still standing and in many cases in primary condition, resulting in a Very Good rating.

Montane forest ecosystems (page 46)

Nearly all Borneo's montane forest ecosystems are within the HoB, and the 89% of remaining forests are generally still in primary condition, resulting in a Very Good rating. These areas have a high rate of local endemism for animals and plants.

Peat swamp ecosystems (page 50)

Peat swamp ecosystems occur mainly in the wide coastal lowlands. Many areas have either been converted or are highly disturbed. Interior peat swamp areas are generally in better condition, and 72% of historic peat swamp in the HoB is still present, resulting in a Good rating.

TOP: Peat swamp forest in East Kalimantan.
Photo: Stephan Wulffraat

Table 1: Sources of historic and current ecosystem extent in the HoB.

Ecosystem	Historic source	Current source
Lowland rainforest	Lowland rainforest was considered to be those areas of HoB forest between 0 and 300 m elevation (based on SRTM 90 m data) not identified as mangroves, limestone forest, peat swamp forest, freshwater swamp forest, heath forest or karst	Historic extent modified with SarVision (2008)
Upland rainforest	Upland rainforest was considered to be forest between 301 m and 800 m elevation (based on SRTM 90m data) not previously identified as mangroves, limestone forest, peatswamp forest, freshwater swamp forest, heath forest or karst	Historic extent modified with SarVision (2008)
Montane forest	Montane forest was considered to be those areas of the HoB above 801 m elevation (based on SRTM 90m data) not previously identified as limestone forest, peat swamp forest, freshwater swamp forest, heath forest or karst	Historic extent modified with SarVision (2008)
Peat swamp forest	Wetlands International peatlands dataset (Wahyunto & Subagjo 2004) and the Biodiversity Information Monitoring System (BIMS) dataset (Mackinnon 1997)	Historic extent modified with SarVision (2008)
Limestone forest	The Geology of Borneo Island (Tate 2001)	Historic extent modified with SarVision (2008)
Heath forest	Biodiversity Information Monitoring System (BIMS) dataset (Mackinnon 1997)	Historic extent modified with SarVision (2008)

Table 2: Remaining extent of major ecosystems in the HoB.

Ecosystem	Remaining extent (km²)	% of historic extent	Proposed desired %
Lowland rainforest	58,897	63	50-60% (Good)
Upland rainforest	89,879	82	60-80% (Very Good)
Montane forest	38,511	89	80% (Very Good)
Peat swamp forest	6,572	72	70% (Good)
Limestone forest	386	79	60% (Good)
Heath forest	4,285	48	60% (Good)

Limestone forest ecosystems (page 52)

Limestone ecosystems are scattered throughout Borneo, but the only large areas are in the Sangkuliran peninsula in East Kalimantan and in the northernmost part of South Kalimantan. These two areas are partly degraded. The smaller limestone areas in the interior are all in good condition. Degradation of limestone ecosystems is usually irreversible. The extent of limestone forest is above the viable threshold of 60% and is also rated as Good.

Heath forest ecosystems (page 54)

Originally, there were large stretches of heath forest, particularly in Indonesian Borneo. Our analysis shows that few wide areas of heath forest remain, and these are mainly in central and east Kalimantan. Even the remaining areas are not completely in pristine condition, as several areas have been burned in the past 25 years. A viable long-term extent of heath forest is proposed to be approximately 60%. Existing heath forest in the HoB is 48% of historic, so this indicator is considered to be Fair.

Note: Many of the smaller and patchy areas of heath forest and limestone ecosystems were not mapped. Habitats smaller than about 20 km² need to be addressed in smaller-scale initiatives.

River ecosystems (page 56)

Table 3 shows the percentage of intact watershed for the major rivers of the HoB relative to the estimated desired percentage.

An interesting map was created which shows the forest cover in percentages of the drainage areas of all the rivers that flow from the HoB. It is clearly visible from this map (on page 57) that forest cover of the drainage areas in the southern, western and northern part of Borneo is generally rather low, while in the northern part of Kalimantan (eastern HoB) conditions are better.

The available remote sensing imagery data did not allow the measurement of one of the original indicators of freshwater ecosystems: the amount of canopy cover within a 100 m buffer along the river. As yet undocumented indicators are discussed in a later section of this report (see page 34).

Table 3: Remaining percentage of intact watersheds for major rivers in the HoB.

Major river	Current extent	% of historic extent	Proposed desired %
Kapuas	39,230 km^2	47% (85% montane, 60% upland, 15% lowland, 50% peat swamp)	Fair (50-70% montane, 40-60% upland, 20-40% lowland, 50-70% peat swamp)
Barito	38,020 km^2	63% (90% montane, 65% upland, 40% lowland, 60% peat swamp)	Good (70-90% montane, 50-70 % upland, 20-40 % lowland, 50-70% peat swamp)
Mahakam	41,130 km^2	54% (90% montane, 55% upland, 30% lowland)	Fair (70-90% montane, 40-60% upland, 20-40% lowland)
Kayan	28,280 km^2	95% (100% montane, 60% upland, 60% lowland)	Very Good (80-100% montane, 60-80% upland, 40-60% lowland)

Keystone species

The compilation and analyses of the status data for the keystone species indicators was a more complicated exercise than for ecosystems, with uneven data availability between species.

Appendix 1 lists all the species indicators, and Table 4 summarises what information is available. There has been extensive research on orang-utans, rhinos and elephants, but most spatial and field data are from outside the HoB.

Elephants (page 82)

Elephants and banteng have similar ecological roles and use of habitat, and uneven and patchy distributions, and so were grouped into one conservation target – forest-edge herbivores.

The elephant distribution may be patchy because it is an introduced species, while the patchy banteng distribution may be because it has been heavily hunted (E. Meijaard, pers. comm.) and its dependence on grasslands surrounded by forests.

The elephants of Borneo, which are mainly in Sabah, have suffered from habitat conversion in recent decades. Population size, distribution and connectivity are the major indicators. The total population size remains relatively stable, since elephant herds move from destroyed habitats into protected habitats (Alfred 2008, Wulffraat

Table 4: Availability and sources of information for key species in the HoB.

Species	Indicator(s)	Data source	Results and rating	Proposed desired rating (see criteria in Appendix 1)
Bornean elephant	Population size Population distribution Genetic connectivity	Alfred et al, 2008, Wulffraat 2007	Population size = 2000 individuals (Good) 60% of historical distribution (Good) 50% of population habitats connected (Fair)	Good = 1,500-2,000 individuals Good = 60% of historical distribution Good = 70% of populations connected
Banteng	Presence in known sites	?	Insufficient information	Insufficient information
Sumatran rhinoceros	Population size	Payne, pers. comm.	Population size <20 individuals (professional estimate) (Poor)	Fair =Population size = 75-100 individuals
Orang-utan	Densities in peat swamp Densities in lowland rainforest	Caldecott & Miles, 2005	Peat swamp forests = 0.61 individ/km^2 (Fair) Present in 50% of all peat swamp forests (Good) Lowland rainforests = 0.48 individ/km^2; present in 40% of all lowland rainforests (Fair)	Good = >0.85 individ/km^2; present in 70% of all peat swamp forest; Good = >0.75 indiv/km^2, present in 60% of all suitable lowland rainforests.
Bornean clouded leopard	km^2 of suitable habitat	Estimation by S. Wulffraat, based on Wilting et al.	165,000 km^2 of suitable habitat (Good)	Good = 150,000-250,000 km^2 of suitable habitat
Bearded pigs	Presence of large numbers @ representative sites Group size @ representative sites Fat condition @ representative sites	?	Insufficient information Insufficient information Insufficient information	Insufficient information Insufficient information Insufficient information
Endangered plant species	% of viable historic locations of endemic Nepenthaceae	Clarke, 1997	80% of historical locations still viable (Good)	Good = 80 % of historical locations still viable

2007). The proposed desired rating for elephant population size is only Good (seen as the best long-term scenario, requiring constant management to keep elephants in the HoB).

Information on banteng distribution is very limited and the occurrence of these wild cattle cannot be directly correlated to landscape ecological characteristics. Banteng have only been documented in a few areas in Borneo. Although we know that they prefer grasslands and young secondary vegetation within forested areas, this does not imply that all these habitats have banteng (Hedges & Meijaard, 1999).

Because there is insufficient information to characterise the viability of banteng, it was decided to split the 'forest edge herbivores' into two targets for the time being. Once sufficient banteng data has become available the original target can be applied.

Sumartran rhinoceros (page 88)

The only sites where there is still an opportunity for Sumatran rhinoceros to survive are in a few protected areas in Sabah, partly outside the HoB. The occasional records from other areas most likely refer only to single individuals and not viable populations. WWF in Sabah keeps records of all rhinoceros sightings and is compiling updated documentation (Payne, pers. comm.). The estimates in Table 4 are the latest from the WWF team in Sabah. The proposed desired rating for rhinoceros is only Fair, since that is estimated to be the best long-term scenario, requiring constant management to keep rhinos in the HoB.

Orang-utans (pages 92 to 96)

Orang-utan distribution maps indicate a rapid decline of habitats (Payne & Prudente, 2008). The major habitats are peat swamp and lowland Dipterocarp forests. Accurate and more detailed information on distribution and densities has become available recently (Husson et al, 2009).

Orang-utans are monitored in several protected areas and more data are gradually becoming available from areas outside the HoB, such as Sebangau, Gunung Palung, Tanjung Puting, Lanjak-Entimau, and Kinabatangan (Rijksen & Meijaard, 1999). Population density estimates in Table 4 are based on Caldecott & Miles (2004).

Clouded leopard (page 90)

Suitable habitats for viable populations of clouded leopards could effectively be identified and mapped by combining landscape ecological characteristics and ecological knowledge. For the purposes of evaluating the status of the HoB, and considering their dawn/dusk and nocturnal habits (Wilting et al, 2006), as well as absence of deliberate commercial hunting pressure, it is assumed that intact appropriate habitat contains clouded leopards. Based on this assumption, the viability can be classified as Good, with relatively large areas of suitable habitat still present.

Endemic plants (page 98)

Endangered plant species are represented by the rare endemic pitcher plants (Nepenthaceae), for which distribution records exist for most species. These endemic pitcher plants serve as good indicator species since they grow mainly in fragile habitats. Several species are restricted to mountain summits in Sabah, which are all in national parks. A number of species occur only in locations without any legal protection status. The relatively high level of attention to these rare species provides some form of protection. Information was obtained from Clarke (1997). The estimated rating for endemic Nepenthaceae is Good.

BELOW: A group of bearded pigs in a conservation area of an oil palm plantation (REA Kaltim) in East Kalimantan. Photo: Ingan Njuk, Kahang Aran & Deni Wahyudi

Bearded pigs

The presence of large numbers of bearded pigs is a good indicator for the functioning of forest ecosystems with special significance to local communities, since wild pigs are a major source of protein. Obtaining this information is more complicated than originally anticipated and will need large-scale field research. Reliable and quantitative data on bearded pigs exist only for a few study areas (Curran & Leighton, 2000). The possibility of extrapolating this information to other areas of Borneo (especially the HoB) is under investigation.

Threat Status

All current and potential (anticipated within the next 10 years) direct conservation threats were linked to biological targets in a conceptual model (box & arrow diagram – see Appendix 2).

Each combination of potential and current threats vs. biological target was on 4-point scales of scope, severity and irreversibility. A combined threat rating was then calculated for each threat-biological target combination using Miradi conservation planning software (Miradi 2009). All threats were combined using Miradi, and then sorted to reveal those threats that were most serious across the HoB. This process clearly indicated the highest threats and the most threatened targets. This table is presented as Appendix 3.

As listed in the previous chapter, the top threats for the HoB are:

- industrial conversion of natural forests
- illegal logging
- legal commercial but unsustainable rates of timber extraction
- forest fire
- mining
- over-hunting and collecting.

The conservation measures team focused on obtaining quantitative data for those threats. Unfortunately, data for these threats across the HoB was not easy to locate.

Available data are summarised in Table 5.

The associated Threat Maps are:

- Lowland rainforest ecosystems: risk of burning (page 64)
- Upland rainforest ecosystems: risk of burning (page 66)
- Montane forest ecosystems: risk of burning (page 68)
- Peat swamp ecosystems: risk of burning (page 70)
- Heath forest ecosystems: risk of burning (page 72)
- Forest fire: fires by year (page 58)
- Forest fire: fires in logging concessions (page 60)
- Forest fire: fires by forest habitat (page 62)
- Mining (no map) (page 79)
- Illegal logging (no map) (page 81)

Table 5: Availability and sources of information for threats in the HoB.

Threat	Indicator	Data Source	Results
Industrial conversion of natural forests	1. Annual rate of conversion 2. Annual plans for conversion 3. Forests within plantations	1. Satellite images analysis 2. Ministry of Forestry (BAPLAN) 3. Landcover GIS analysis	1. Current locations and areas (hectares) 2. Planned locations and areas 3. Forest types affected
Illegal logging	Incidence	Point records from Polhut, regular police, CIFOR, WWF Indonesia	Locations and timber volumes of a limited number of incidences
Legal commercial but unsustainable rates of timber extraction	Percentage of crown cover in logged forests within individual logging concessions	Not available (assessment still in experimental stage)	
Forest fire	1. Annual number and extent of fires 2. Fires in logging concessions 3. Fires in the various ecosystems	1. ESA Hotspots ATSFire website 2. Satellite image & hotspots analysis 3. Satellite image & hotspots analysis	1 Annual hotspot locations over a 14-year period 2 Hotspot locations within concessions 3 Hotspots in each major ecosystem
Mining	Existing extent; projected extent	Not yet available	
Over-hunting and collecting	Areas with animal populations strongly declining	Only possible with indicative areas based on 'guesstimates'	

Conservation Management Status

Conservation management (and social well being indicators) are additions to Parrish et al (2003) and Gordon et al (2005), intended to create a more comprehensive baseline assessment of the conservation status of each place.

Conservation management status is "a measure of the likelihood that protection and management activities will secure biodiversity and allow it to persist. This measure is defined by the intent, duration, and potential for the management to be effective where these activities are in place" (Higgins et al, 2007). The components of conservation management can include, but are not limited to:

> representation of all habitat types within protected areas (Noss, 1992);

> management effectiveness of protected areas (Hockings et al, 2006, Stolton et al, 2007);

> conservation financing (James et al 1999); and

> the associated legislation, regulations and/or legal structures.

Representation of ecosystems and species in protected areas is seen as the most basic component of conservation management status. For the HoB, conservation management indicators were focused mainly on identifying areas with a protected status for each biological target. The status of forest areas within logging concessions is also a focus, which ensures that at least for the near future these forests are being retained, albeit in a less than pristine state.

The associated Conservation Management maps are:

> Lowland rainforest ecosystems: status (page 41)

> Upland rainforest ecosystems: status (page 45)

> Montane forest ecosystems: status (page 49)

> Orang-utans: average density in protected areas (page 97).

Table 6: Availability and sources of information for conservation management in the HoB.

Target	Indicator	Data sources	Results
Protected area representation	1. % of peat swamp forest in protected areas 2. % of lowland rainforest in protected areas 3. % of upland rainforest in protected areas 4. % of montane forest in protected areas 5. % of heath forest in protected areas 6. % of limestone forests in protected areas 7. % of orang-utan habitat in protected areas	GIS analyses of forest types maps (see Biological Targets) and protected areas map from Ministry of Forestry	1. There are only very small areas of peat swamp forests in protected areas in the HoB (Danau Sentarum). 2. 9.6% of the remaining lowland rainforests in the HoB legislated. 3. 18% of the remaining upland rainforests in the HoB legislated. 4. 29% of the remaining montane forests in the HoB legislated. 5. No or only very small areas of heath forest in protected areas in the HoB. 6. No or only very small areas of limestone forest in protected areas in the HoB. 7. 6% of the remaining lowland rainforests in the HoB legislated. (Not all remaining lowland rainforests are inhabited by orang-utans.)
Protected area intactness	% of intact natural habitats in protected areas	GIS analysis of forest cover map (from Modis 250 m) and protected areas map from Ministry of Forestry	94% of protected areas of the HoB have forest cover
% of remaining forest in concessions	% of production forest that remains forest	GIS analysis of forest cover map (from Modis 250 m resolution images) and concessions map from Ministry of Forestry	3,748,000 ha of remaining forest-covered land is within concessions: 31% of the remaining lowland rainforests, 20% of remaining upland rainforests, 20% of remaining montane forests
Enforcement of existing legislation	Peat conversion	Forest cover map time series, peat swamp ecosystems map	Indications whether any peat swamp ecosystems have been converted

The HoB protected areas

Classification and designation of protected areas in the Heart of Borneo (HoB) varies for each country and state.

Sarawak has three classes of protected area, all under the governance of the Forest Department: National Parks, Wildlife Sanctuaries and Nature Reserves. National Parks are relatively large areas while Nature Reserves are less than 1,000 ha.

Sabah uses a different approach. There are the State Parks, the largest protected areas, managed by Sabah Parks.

All other areas that are to be maintained as forests are designated as Forest Reserves. The seven classes of Forest Reserves include Commercial Forest (class II). This class, with the largest total area, covers timber production forests with logging concessions. Important protected area classes are Protection Forest (class I), Virgin Jungle Forest (class VI) and Wildlife Reserve (class VII). All Forest Reserves are governed by the Sabah Forestry.

Brunei distinguishes five functional categories: Protection Forest, Conservation Forest, National Park, Recreation forest and Production Forest.

The management of the forests of Brunei is under the jurisdiction of the Forestry Department, a division of the Ministry of Industry and Primary Resources.

Kapuas mud snake (Enhydris gyii) The half-metre long poisonous snake was described as a new species in 2005 by the German biologist Dr Mark Auliya. It was discovered in the wetlands and swamped forests of Sungai Kapuas near the Betung Kerihun National Park.
Photo: © WWF Indonesia / Mark Auliya

Indonesia has six classes of protected areas. National Park (*Taman Nasional*), Nature Reserve (*Cagar Alam*) and Protection Forest (*Hutan Lindung*) are the largest and most important ones. Some areas that were originally designated as Wildlife Reserve have become National Parks to better accommodate specific requirements, such as access to the area by local communities. The Wildlife Reserve status is a very strict protection status (comparable to IUCN category Ib) that does not allow access to non-timber forest products. National Parks and Wildlife Reserves are under the governance of the Ministry of Forestry.

The Indonesian Protection Forest (*Hutan Lindung*) is a weaker status of protection. It was originally designed by the colonial government to ensure that the forests on the steep slopes and higher elevations of the mountains on Java were protected, mainly to serve their hydrological and erosion protection functions. The classification was later applied to Kalimantan and other parts of Indonesia, so that all forests on steep slopes (>40%) would automatically become protection forests. The total area of protection forests within the HoB is relatively large, at least on the forest use maps. The status is not always strictly enforced and illegal logging, mining and encroachment occur. Protection Forests are under the governance of the local District (Kabupaten) governments. Approval from the Ministry of Forestry is still needed if a local government wants to change to status of a Protection Forest.

Danum Valley forest in the morning light. Photo: © WWF Canon / Alain Compost

National Parks and State Parks

National Park status in Indonesia, Sarawak, Brunei and Sabah corresponds to IUCN Category II.

Betung Kerihun, at 800,000 ha, is the second largest protected area in Borneo. This West Kalimantan National Park ranges from the northern foot-slopes of the Kapuas drainage area to the mountain range that forms the water divide and border with Sarawak. The continuous intact ecosystems of Betung Kerihun range from lowland rainforest to montane forests. Betung Kerihun, together with Danau Sentarum, harbour the world's largest population of the orang-utan sub-species *Pongo pygmaeus pygmaeus*.

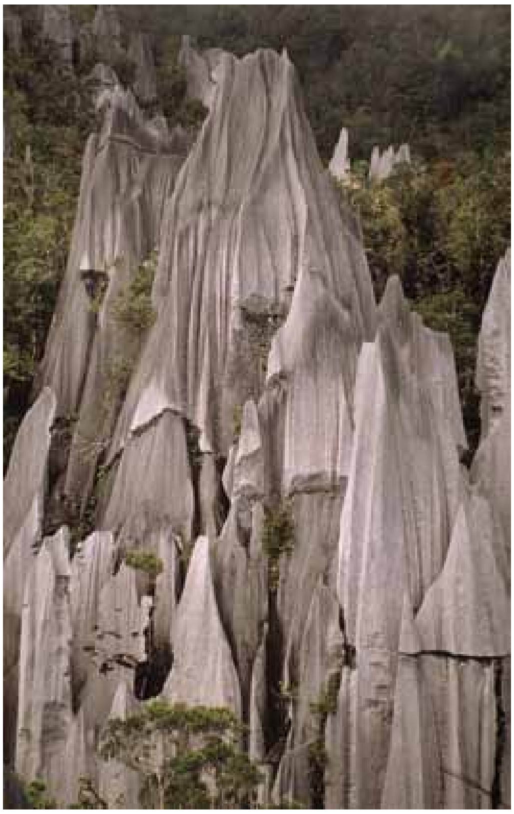
Danau Sentarum National Park (132,000 ha) is the largest freshwater ecosystem in the Heart of Borneo. It is part of the Kapuas drainage area and has numerous floodplain lakes that are subject to strong seasonal water level fluctuations. The lakes are surrounded by various types of swamp forest with many unique species including endemic plants and fish, the largest inland population of proboscis monkey, and 2-3 crocodilian species. Danau Sentarum is south of Betung Kerihun and a corridor is being developed to connect these two National Parks and their orang-utan populations.

Batang Ai in Sarawak is a relatively small National Park at 24,040 ha. It is, however, an essential conservation area as it connects to Lanjak Entimau Wildlife Sanctuary and Betung Kerihun National Park across the border. The lowland rainforests of Batang Ai are the catchment area of an artificial hydro-power lake and home to an important orang-utan population.

Pulong Tau National Park in Sarawak (59,817 ha) is close to the border with Kayan Mentarang National Park in East Kalimantan, Indonesia. Between the two national parks is the Kelabit highland plateau, which has a relatively dense human population. Pulong Tau comprises the Tama Abu mountain range and connects through a mountain ridge with Mount Murud in the north. Elevations range from about 500 to 2,400 metres and the forest types include upland, heath, lower montane and upper montane forest.

Gunung Mulu in Sarawak (52,865 ha) is particularly famous for its limestone formations. This National Park has a number of spectacularly large cave chambers connected by hundreds of kilometres of cave passages. Along the slopes of Gunung Api are unique limestone spikes. Mount Mulu itself consists of sandstone rocks. The vegetation is limestone forest and lowland, upland and montane forest. The very diverse flora and fauna includes many endemic species.

Gunung Buda is a small (6,235 ha) National Park connected to the northern part of Gunung Mulu National Park and encompasses the same limestone formation. The Gunung Buda massif has impressive limestone cliffs and many interesting caves as well. The vegetation consists of upland limestone forests and cliff vegetation. The fauna includes several unique species that live in the caves, including rare fish species.



In Gunung Mulu National Park, 150-metre tall limestone pinnacles rise though the Sarawak rainforest canopy. Photo: © Terry Domico/WWF-Canon

Titan Arum of Bunga Bangkai (Amorphopallus titanum) blooming in Betung Kerihun National Park, West Kalimantan. Photo: © WWF Indonesia / Marius Gunawan

Bukit Baka Bukit Raya, in West and Central Kalimantan, is a rather large (181,090 ha) protected area. The area is part of the Schwaner range that forms a central mountain spine from west to east along which the park is centred. The highest peaks of this mountain ridge, which forms the boundary between West and Central Kalimantan are Bukit Baka and Bukit Raya. The national park stretches along both northern and southern slopes of the mountain ridge. The southern part includes some lowlands.

The 1.4 million ha **Kayan Mentarang National Park** is the largest protected area in Borneo. The National Park is in the interior of East Kalimantan and includes the headwaters of several major rivers all the way to the borders of Sarawak and Sabah. The area has a wide variety of landscapes, ranging from lowland river valleys to high mountain summits, forming an enormous diversity of habitats. Kayan Mentarang probably has the highest habitat diversity of all protected areas in Borneo and consequently species richness is extremely high. Most of the area has an elevation of more than 500 m asl and therefore upland and montane forest types are very well represented. The population of banteng (*Bos javanicus*) here is probably the largest in Borneo.

Ulu Temburong National Park (about 50,000 ha) comprises the upper section of the eastern part of Brunei. The area ranges from lowland foot slopes in the north to mountain ridges further to the south where the highest peaks reach above 1800 m. Although relatively close to the coast, the landscape is characterised by typical interior Borneo topography with steep slopes and ridges, dissected by narrow river valleys. A large part is covered by primary lowland and upland Dipterocarp forests, while montane forests dominate the southern part. Many of the ecosystems of Borneo are represented making Ulu Temburong an ideal research area. A field station was established in the central Belalong area and a comprehensive research project conducted here in 1991-92 yielded excellent results on a high number of forest ecology and wildlife subjects.

Rafflesia pricei just opened to full flower. Crocker Mountains in Sabah. Photo: © Gerald S. Cubitt / WWF Canon

Crocker Range is the largest State Park in Sabah (139,900 ha). The park comprises a large section of the Crocker mountain range, located in the western part of Sabah. It includes the forests on both sides of the central mountain spine down to the foot slopes. The vegetation consists mainly of upland and lower montane forest. Part of the upland rainforest is secondary. Crocker Range is rich in species endemic to Borneo.

Kinabalu (75,400 ha) was established in 1964 and so is the oldest Park in the Heart of Borneo. This is probably the best-known protected area of Borneo and is home to Mt Kinabalu and the surrounding massif, which includes the impressive Mt Tambuyukon.

The vegetation shows a gradual transition from upland Dipterocarp forest at the edges of the National Park to lower montane forests, and upper montane forests in numerous classes to low alpine shrub land along the bare rocks of the summit. This is the only place in Borneo where the entire range of upper montane and alpine vegetation can be found and many species are unique to Mt Kinabalu.

The area has an estimated 5,000-6,000 vascular plant species and, given the relatively small size of the area (compared to national parks in Kalimantan), has one of the highest concentrations of plant species in the world.

The rich variety of fauna includes many endemic species. Several were first discovered at Mt Kinabalu, or are found at only a few other isolated high summits.

Climbing the mountain has become a popular tourist attraction that provides the communities living along its slopes with a good source of income.

Strict Nature Reserves – IUCN Category Ia

In Indonesia : Nature Reserve (Cagar Alam)

Sapat Hawung in Central Kalimantan is a relatively unknown protected area in the centre of Borneo that is becoming of major importance by connecting extensive forest areas of three provinces. Elevations of the 239,000 ha area range from about 300 m asl in the river valleys of the south up to 1700 m for the summits of the northernmost mountain ridges. The uplands and mountains along the northern border of Central Kalimantan form the water divide between the upper Barito and upper Mahakam rivers. Most of the forest is in primary condition.

In Sabah, Forest reserve class VI: Virgin Jungle Reserve

Maligan (9,200 ha) is in the mountain complex of south-west Sabah, bordering Sarawak. The forest is in primary condition. The geomorphology is very diverse and several types of montane vegetation types can be distinguished, ranging from montane alluvial forest on river levees to shrubby heath forest at the summits of sandstone cuestas. Of particular interest are the montane peat swamps, which have developed in depressions with poor drainage.

The Conservation Forests of Brunei

These are strict nature reserves. There is Ulu Mendaram along the western border and Sungai Ingei along the southern border of Brunei.

Protection forests

This corresponds to IUCN Category VI Managed Resource Protected Area.

The Indonesian part of the HoB has many Protection Forests (*Hutan Lindung*). Nearly all of these comprise mountainous and hilly areas with steep slopes.

Important protection forests in West Kalimantan that are habitats of endangered species include Bukit Perai, Bukit Rongga, Bukit Tenobang and relatively large areas of the upper Kapuas.

Bukit Batikap is an important area of Protection Forest in the upper northwestern part of Central Kalimantan. It is part of the Muller-Schwaner mountain range which connects forest areas of the upper Kapuas (Kalbar) and upper Barito drainage areas. The Bukit Batikap connects to the Sapat Hawung nature reserve through the upper Busang. Both areas were investigated during the LIPI expeditions of 2003-2005.

Along the border between Central and East Kalimantan are several smaller areas of protection forests, such as the Maruwai area, that comprise the steepest slopes of the watersheds.

In East Kalimantan are several larger areas of protection forest such as Gn. Raga, Batu Brok, Hulu Tubu, Hulu Kayan and Hulu Belayan. These will become important to consider for ensuring connectivity and sustainable land use in the HoB.

In Sabah, this is Forest reserve class I (Sabah): Protection Forest

Danum Valley Conservation Area (43,800 ha) was set aside from logging in 1980 and is managed by the Sabah Foundation. One of the major purposes of Danum Valley is to serve as a tropical forest research and education centre. Accessability to the field centre (established in 1986) is very good and an extensive network of trails and numbered forest blocks has been established in the surrounding lowland Dipterocarp forest. Most of the lowland mammal and bird species can be observed here. Many scientific projects have been undertaken and published since the 1980s, resulting in increased knowledge of the ecology and wildlife of Borneo's lowland rainforests.

The Maliau Basin Conservation Area of 58,840 ha comprises a spectacular landscape in the shape of a very large crater. The geology however is of sedimentary original, consisting mainly of sandstone and mudstone. Most of the basin itself is surrounded by steep cliffs and the only easy access is in the southeastern section, where all streams of the basin converge into the Maliau river. The conservation area also includes the forests to the north and east of the rim, as well as the Linumunsut lake. The area was set aside from logging by The Sabah Foundation and scientific investigations only started some 20 years ago but have since been advanced with vigor. Most of the area is covered by montane and heath forest types that harbour many unique species.

The Imbak Canyon Conservation Area is currently being established by combining the two ridge summit Virgin Jungle Reserve with the valley (canyon) of the Imbak river in between. The area, located to the north of Maliau Basin, is about 30,000 ha and has some of the last primary lowland Dipterocarp forests of Sabah.

Many of the forests along the southern border of Brunei are Protection Forests.

Wildlife Sanctuary Reserve

IUCN Category IV

Lanjak Entimau Wildlife Sanctuary, with an area of almost 200,000 ha, is the largest protected area in Sarawak. It comprises the upstream section of the Rajang and other rivers and consists mainly of hilly to mountainous terrain. Most of the area is covered by primary lowland and upland rainforests, while patches of secondary forests exist mainly in the lowlands.

Nature Recreation Park (*Taman Wisata Alam*)

This class falls within IUCN Category III.

Gunung Kelam TWA in West Kalimantan is a small (520 ha) protected area comprising three hills of which Mt. Kelam is the largest and highest (936 m asl). It is relatively well known because the critically endangered pitcher plant species *Nepenthes clipeata* is endemic to Gunung Kelam and found nowhere else in the world. The area is officially a nature recreation park, but access to the rare pitcher plants is often controlled.

Rajang River, Sarawak.
Photo: © WWF Canon / Chris Elliot

The HoB's highest mountains

Most of the mountain ranges in the interior of Borneo are connected, which led to the expression of 'the central mountain spine' of Borneo. The first concept for the Heart of Borneo encompassed this 'spine' plus its foot slopes.

The mountains of Borneo were formed over millions of years through complex geological processes. Movements of tectonic plates pushed layers of the earth crust to high elevations and the intense pressure at colliding layers changed base materials into newer rocks. These metamorphic rocks are the oldest known materials in Borneo and surface in certain areas, particularly in the west. The most common rock types are schist and gneiss.

Later, most of Borneo was below sea level for millions of years and became covered by layers of sediments settling at the bottom of the sea. These sediments gradually developed into rocks. The sedimentary rocks of the interior later eroded, forming elongated ridges. In some areas, coral reefs developed and evolved into limestone formations. The most common sedimentary rock type in Borneo is sandstone.

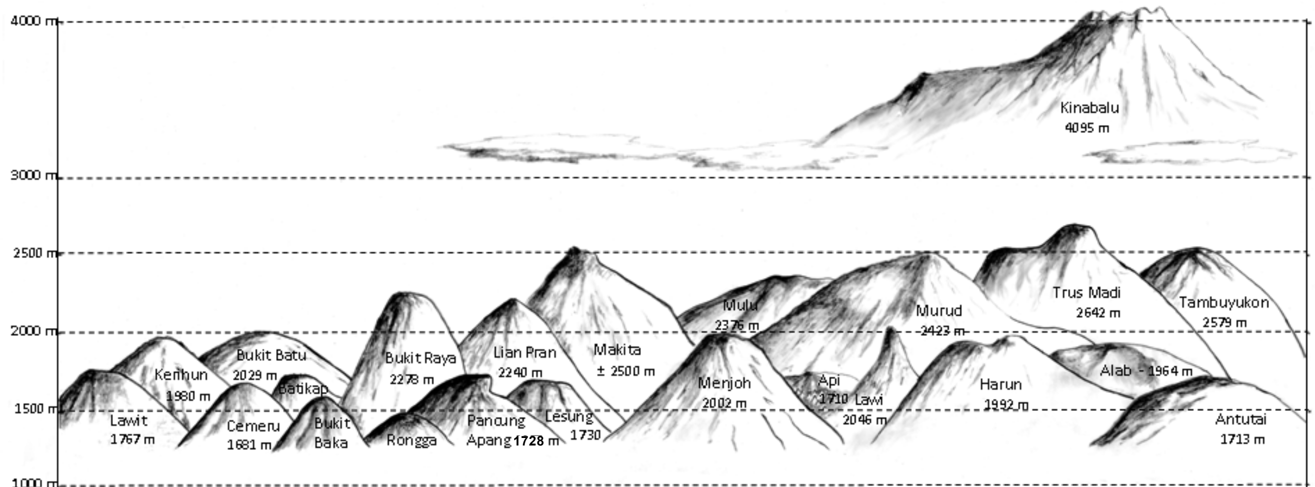
A part of Borneo, mainly in East Kalimantan, was affected by volcanic activity during a period of time. Volcanic mountains were formed by deposits of material from eruptions that burst through the earth crust. Basalt is the most common material.

Even though none of the old volcanoes are active, their geological origins are easily recognised, especially on satellite images. These mountains have a radial drainage pattern, each deriving from a central peak. The sedimentary mountains, on the other hand, are usually merely the highest parts of ridges, without a distinctive drainage pattern.

Magma from deep inside the earth occasionally formed intrusions and large formations of plutonic rocks (frozen magma) were pushed upwards, forming hills and mountains. Granite is the best known plutonic rock.

Batu Lawi Bario Sarawak. Photo: Gustino Basuan

Diagram showing the highest mountains of Borneo for comparison.



Created by Syarif Wulffraat

Sabah

Plutonic formations are not common on the surface of Borneo but the best known mountain is of this geology. At 4,095 m, Mount Kinabalu is by far the highest mountain in Borneo; no other mountain reaches even 3,000 m. The Kinabalu massif consists of a giant mass that moved upwards through older formations of the earth crust. This movement continues: the mountain rises some 5 mm per year. The base material is granodiorite, a rock type similar to granite but with a slightly different composition and a darker appearance.

Mt Tambuyukon, at 2,579 m the third-highest mountain of Malaysian Borneo, is in the northern part of the Kinabalu massif. One of the few other plutonic mountains in Borneo is Bukit Rongga (1,506 m) in West Kalimantan.

Mt Trus Madi, the second-highest mountain of Malaysian Borneo (2,642 m), has a rather complicated geology. Although mainly consisting of sedimentary materials, such as mudstone and shale, a long history of folded and faulted layers has given rise to a variety of other rock formations, even including locally formed metamorphic rocks.

The Crocker range is an extensive sedimentary hill and mountain complex. Although it connects to Mt Kinabalu, it has a completely different geology. The sedimentary mountain ridges have rather high summits, of which the highest is Gunung Alab (1,964 m).

The central part of Sabah consists mainly of sedimentary materials. One of the highest peaks is Gunung Antulai (1,713 m) in the south. The cliffs around the Maliau basin also reach elevations of up to 1,667 m.

Tunku Abdul Rahman Peak (3,948 m) from the stunted forest at about 3,200 m in the Mount Kinabalu National Park. Sabah. Photo: © Gerald S. cubit/WWF-Canon

Sarawak

Gunung Murud (2,423 m), close to the border with East Kalimantan, is the highest mountain of Sarawak. The major base material of this sedimentary mountain is sandstone. Gunung Murud was once considered a spiritual mountain, and a church camp has been established not far below the summit.

Nearly all the mountains of the interior of Sarawak are of sedimentary geology. The Tama Abu range, just south of Gunung Murud, has several high ridge summits, of which Bukit Batu Buli (2,082 m) is the highest.

To the west is Bukit Batu Lawi with its characteristic 2,046 m pinnacle. The exposed rock faces appear white and the pinnacle was previously mistakenly identified as limestone. It is, in fact, hard sandstone that remained while the surrounding softer materials eroded away.

A bit further to the west is Bukit Batu Iran, a 'regular' sedimentary mountain of almost the same height (2,018 m).

Gunung Mulu National Park is best known for its limestone formations and Gunung Api (1,710m) and Gunung Benerat (1,615m) are impressive examples of limestone peaks. The 2,376 m high Gunung Mulu itself, however, consists mainly of sandstone.

The Hose mountain range, along the middle course of the Rajang river in central Sarawak, has a summit of 2,029 m, simply called Bukit Batu.

All the other high mountains of Sarawak are in the headwaters of the major rivers along the border with Indonesia. The upper Baleh area in particular has many high elevations, above 1500 m asl.

West Kalimantan

Most of the highest elevations of West Kalimantan are in the north and east. These mountains are among the oldest in Borneo and consist largely of metamorphic materials.

Most of the northern mountain range is encompassed in the Betung Kerihun National Park, where the water divides have high elevations. The highest peaks are, from west to east, Gunung Lawit (1,767 m), Gunung Kerihun (1,980 m) and Gunung Cemaru (1,681 m). Gunung Cemaru is a water divide for the Kapuas, Mahakam and Baleh rivers.

The highest mountain of West Kalimantan, Bukit Raya (2,278 m), is shared with Central Kalimantan. This mountain ridge is connected further to the west to Bukit Baka (1,617 m) and the much lower Gunung Tikung.

Gunung Niut (1,701 m) is relatively close to the coast and outside the HoB delineation, but should be mentioned here as it is the only volcanic mountain in West Kalimantan. All others are in East Kalimantan.

Central Kalimantan

The Schwaner mountain range in the western part of Central Kalimantan has with Bukit Raya the highest peak of this province.

Most of the other high mountains are in the northernmost part of Central Kalimantan, the headwaters of the upper Barito river. This area is mainly of sedimentary geology, with intrusions of volcanic formations in various edge locations.

Bukit Batikap is a complex of asymmetric broadly dissected ridges, with a highest peak of 1,744 m. The major base materials are sandstone and mudstone.

Further to the east are more sedimentary ridges and three summits are distinguished here, being Mt Pancungapang (1,728 m), Lesung (1,730 m) and Batu Ayau (1,652 m). All three summits are identified as sandstone cuestas, tilted ridges with escarpments on their sides.

East Kalimantan

A problem in East Kalimantan is that elevations on the regular topographic maps are not reliable. Summit elevations are often too high on the maps. For instance, Gn. Menjoh is displayed as being 2,550 m high, while in reality it was measured to be 2,002 m; Gn. Harun, shown as 2,160 m high, was found to be 1,992 m. Gn. Makita is shown as 2,987 m high, which would make it the second highest mountain of Borneo. However, it is estimated that the summit is less than 2,500 m.

Most of the mountains of East Kalimantan are of sedimentary origin and their present shapes are the result of millions of years of erosion.

In addition, East Kalimantan has larger stretches of volcanic formations, which are located mainly in the westernmost part. The volcanic mountains, though not active anymore, are much younger than the surrounding sedimentary geology. Most are shaped like strato-volcanoes, though erosion has taken off any crater rim or steep cone.

The first ones in a S-N row of volcanic mountains are Mt Liangpran (reportedly 2,240 m high) and the connecting Mt Batubrok (1,546 m). This massif is along the uppermost stretch of the Mahakam river. Gn. Makita, the highest mountain of Kalimantan, borders the Apo Kayan area. It has several other local names.

Further to the north are several other volcanic mountains and most are inside the Kayan Mentarang national park. Gn. Lunjut has a narrow peak while the neighbouring summit of Gn. Menjoh has the shape of a rim. Several new plant species and new bird records were discovered here. The mountain complex west of the Lalut Birai research station, with elevations up to 1,820 m, was investigated during the long-term research program.

The numerous sedimentary mountain ridges of the interior of East Kalimantan can also reach high elevations. Gn. Menyapa and other mountains in the upper Belayan are mapped as more than 2,000 m high. Kong Kemul, between the Telen, Kelai and Kayan rivers, is 1,807 m high.

Gn. Harun in the very north has been documented in some detail for geomorphology, soils, vegetation, mammals and birds.

The HoB's forests

Some characteristics of the main HoB forest types.

	Lowland rainforest	Upland rainforest	Lower montane forest	Upper montane forest	Heath forest	Peat swamp forest
Main forest types	Lowland Dipterocarp Ironwood forest Secondary forest types	Hill Dipterocarp Mixed hill forest	Montane Oak-Myrtle Upper Dipterocarp Montane ridge forest	Upper Oak-Myrtle Elfin forest	Conifers dominated Palaquium dominated Myrt.-Gutt. Dominated	Gluta-Fagraea dom. Cratoxylon forest
Canopy height	25-40 m	20-35 m	15-25 m	5-15 m	10-20 m	10-25 m
Strata	4-5, very heterogenous	4-5, not easy to distinguish	3-4, easy to distinguish	often only 2	3-4, not easy to distinguish	3-4, easy to distinguish
Emergent trees	Characteristic	Common	Not so many	Almost absent	Few	Not many
Height of emergents	to 65 m	to 50 m	to 40 m	to 25 m	to 35 m	to 35 m
Overall tree density	Rather open	Rather open	Rather dense	Dense	Very dense	Dense
Ground layer	Thin, dense in few spots	Thin, dense in some spots	Rel. dense herb layer	Dense herb/ moss layer	Very dense herb layer	Dense in certain spots
Tree diameters	Very big trees common	Big trees frequent	Usually <80 cm	Usually <40 cm	Usually <60 cm	Usually <60 cm
Buttresses	Common and large	Common but not very large	Uncommon, small	Usually absent	Usually absent	Usually absent
Cauliflory	Frequent	Frequent in certain spots	Rare	Absent	Rare	Rare
Big lianas	Abundant	Abundant	Few	Absent	Few	Few
Epiphytes	Frequent	Often abundant	Abundant	Frequent	Abundant	Abundant
Mosses	Occasional	Frequent	Abundant	Very abundant	Abundant	Often abundant
Principal leaf size class	Mesophyll	Mesophyll	Notophyll or mesophyll	Microphyll	Notophyll or microphyll	Mesophyll or notophyll
Compound leaves (trees)	Frequent	Frequent	Rare	Very rare	Rare	Rare
Bi-pinnate leaves (trees)	Frequent	Rare	Very rare	Very rare	Very rare	Very rare
Leaf drip-tips	Abundant	Abundant	Present or common	Rare or absent	Present or common	Abundant

Lower montane forest. Kayan Mentarang, East Kalimantan. Photo: Stephan Wulffraat

The summit of mount Harun in the very north of East Kalimantan. Photo: Stephan Wulffraat

Peat swamp forest along Jempang Lake, East Kalimantan.
Photo: Stephan Wulffraat

Primary lowland forest with Licuala palms in the under-storey. Murung Raya, Central Kalimantan.
Photo: Stephan Wulffraat

Dense heath forest with many pitcher plants. Kayan Mentarang, East Kalimantan.
Photo: Stephan Wulffraat

The HoB's riparian forests

Riparian forest is an important ecosystem in the Heart of Borneo. The National parks of Betung Kerihun, Danau Sentarum, Bukit Baka-Bukit Raya and Kayan Mentarang, as well as the corridors connecting these areas, have extensive stretches of good riparian forest along their major rivers.

Generally, riparian forest reaches its optimum development below about 200 m and where the rivers have wide plains.

The riparian landscape has varied terrain throughout the downstream, middle and upstream course of the river.

The upstream section often has steep riversides with exposed rocks that are being eroded by the river flow. Detailed studies of upstream river courses, such as the Enggeng river in Kayan Mentarang National Park, show the diversity, from flat river plains to very steep banks. These upstream rivers are subject to a dynamic flow regime, where periods of relatively gentle flow are interrupted by sudden floods. Banks formed by river sediments can rapidly change shape or even disappear. The riparian vegetation along these rivers is well adapted to these situations.

The flooding regime of the riparian forests of the middle river course of Danau Sentarum National Park is completely different from the upstream regimes found in Betung Kerihun and Kayan Mentarang. The riparian zone of Danau Sentarum can be inundated for up to six months a year, which affects the riparian vegetation. The best adapted tree species here are *Gluta renghas* and *Fagraea fagrans*.

Rheophytes are plant species that are especially adapted to growing in the flood zone (between normal water level and the high water level caused by floods). Most rheophyte species have special characteristics such as a strong root system, flexible branches and narrow leaves. Important rheophyte species in Borneo include *Dipterocarpus oblongifolius, Saraca declinata, Pometia pinnata, Nauclea rivularis, Osmoxylon helleborinum, Pinanga rivularis, Saurauia angustifolia, Dillenia* sp., *Aglaia elliptica, Diospyros* sp., *Saurauia heterosepala*, and *Syzygium* sp. *Shorea stenoptera* is a common tree species somewhat higher on the riverbanks. This species is an important producer of tengkawang oil (from its seeds) in West Kalimantan and is often planted by local communities. The seeds are also widely distributed through the flow of the river.

Common smaller trees and shrubs of riverbanks include simpur (*Dillenia sp.*), kayu hitam *(Diospyros sp.), Aporosa spp., Polyalthia spp., Goniothalamus sp., Alyxia sp., Macaranga sp., Mallotus sp., Mussaenda sp., Bauhinia sp., Gnetum sp.* and *Ixora laila*.

Several palm species are common, particularly *Areca jugahpunya*, *Pinanga mooreana*, *Plectocomiopsis geminiflora,* palem Birai (*Salacca borneensis*), *S. dransfieldiana*, and *S.vermicularis*. One of the most decorative palm species, with long wavy leaflets, is *Arenga undulatifolia*. Clumps of wild sago palms, *Eugeissona utilis,* often grow on steep rocky banks.

The under-storey of riparian forests is dominated by plant species such as *Etlingera sp., Globba sp., Stachyphrynium sp., Selaginella sp., Ardisia sp., Elatostema sp., Cyrtandra spp., Begonia spp., Achasma macrocheilos,* the giant *Alocasia*, and the bambu *Schizostachyum brachycladum*. The riparian forest floor is, in most places, relatively open, which is caused by the frequent disturbances of floods. In locations with sedimentation, there can be dense growths of particularly Maranthaceae and Zingiberaceae.

Common liana species of riparian forests include *Mucuna biplicata, Spatholobus ferrugineus*, *Tetrastigma lanceolarium, Phanera sp., Spatholobus ferrugineus, Phanera* sp. and *Schefflera* sp. Rattan species that grow here include *Korthalsia* fishtail rattans as well as several *Daemonorops* and *Calamus* species.

Old trees along the river are usually densely covered with epiphytes. Common species are *Asplenium nidus, Drynaria sparsisora, D. quercifolia, Pandanus epiphyticus* and *Freycinetia sp. Rhododendron javanicum* and *R. malaya-num* are conspicuous epiphytes with large orange flowers.

Epiphytic orchids, which need light and high humidity, are particularly well represented by the genera *Coelogyne*, *Bulbophyllum, Dendrobium, Eria, Agrostophyllum,* and *Cymbidium*. The genus Coelogyne has many species that are often found here, such as *Coelogyne asperata* with yellow flowers*, C. foerstermanii* with white flowers,

Aerial view of a river ecosystem in West Kalimantan. Photo: Stephan Wulffraat

C. echinolabium, C. Incrassata, C. dayana and *C. Rochussonii*. The famous black orchid *Coelogyne pandurata* also grows in this habitat, but is rarely found. The giant *Grammatophyllum speciosum* orchid is common along the riversides.

Almost all animal groups – aquatic, arboreal and terrestrial – are found in the riparian forest.

Several mammals of this habitat are endemic, rare and/or endangered, such as the proboscis monkey (*Nasalis larvatus*), orang-utan (*Pongo Pygmaeus*), flat-headed cat (*Felis planiceps*) and clouded leopard (*Neofelis nebulosa*).

Bird species of special interest include the rare Storm's stork (*Ciconia stormi*), the oriental darter (*Anhinga melanogaster*), the lesser adjutant (*Leptoptilus javanicus*) and several internationally protected hornbill species.

Large reptile species of the riparian forest include the estuarine crocodile (*Crocodylus porosus*), the false gavial (*Tomistoma schlegelli*), tortoises, snakes, monitor lizards and even the ranin crocodile (*Crocodylus raninus*). The latter had been thought to be extinct for 150 years, but can still be found in the riparian zones of Danau Sentarum National Park.

For 'Aquatic Biodiversity of Sundaland' in 2007, a team led by Dr Djoko T. Iskandar found an extremely rare endemic frog species, *Barbourula kalimantanensis*, which attracted the attention of amphibian experts all over the world. This is a primitive species, but very well-adapted to live in fast-flowing, clear and cold water. This makes it very susceptible to water pollution. A large number of other, more common, frog species are found in the riparian forests.

Two of the most important fish species for consumption are *Tor tambra* and *Tor tambroides.* A well-developed riparian forest zone is important to the survival of these species because the flowers and fruits of riparian tree species such as *Dipterocarpus oblongifolius* are major food sources for the fish. Attractive species such as *Botia macracanthus* and *Botia hymenophysa* particularly favour the shadow and party submerged boles of the riparian trees.

A major threat to riparian forests is shifting cultivation. Local communities traditionally practise this form of agriculture by periodically clearing a piece of forest. Every family needs about two hectares for a field. After five to 20 years, they will return to a previously used location and cultivate it again. The most convenient locations to open are the forests along the rivers, which is why many of the riparian forests are disturbed or have been converted to agricultural fields and gardens.

Hunting is another threat to the many animals that live in riparian forests. While local communities have a long tradition of hunting, its impact is increasing and it is becoming more difficult to find animals at high densities.

History teaches us that nearly every human community started with a settlement along a river. It is close to water sources, the soils are relatively fertile because of high sedimentation and humus, and the access is easy.

– Albertus Tjiu, Koordinator Biologi Konservasi, WWF Indonesia – Program Kalimantan Barat

The HoB's swamp forests

South-East Asia's freshwater swamps are found mainly in the coastal lowlands, extending inland from behind the mangrove zone. Isolated swamps are found further inland in the middle or upper basins of larger rivers, but are less common.

Before the large-scale commercial logging of the 1980s and 1990s most of Borneo's inland swamp habitats consisted of tall, mixed swamp forests.

Danau Sentarum swamp forests

The largest expanse of inland swamp forests in Kalimantan occurs along the Kapuas River in West Kalimantan, part of the 132,000 ha Danau Sentarum National Park (DSNP), Indonesia's second Ramsar site.

The upper Kapuas basin is very flat, and the Kapuas River tends to pond upstream of a natural 'bottleneck'. Because of high rainfall (>3,000 mm/year), most of the low-lying areas in the basin are flooded in the wetter months. As a result, DSNP consists of a mosaic of various types of swamp forest, along with seasonal lakes that are dark coloured due to peat deposits. These lakes act as a buffer for the Kapuas system, mitigating floods (absorbing a quarter of the peak flood) and maintaining water levels in the dry season. The ecosystem is characterised by an annual rise and fall in water levels of up to 12 metres.

Swamp forest makes up about half the DSNP, with another quarter covered with lakes and the remainder hill forest and (wet) heath forest. There are three major types of swamp forest: tall (average canopy height of 22-30 m), stunted (8-15 m) and dwarf (5-8 m).

Tall swamp forest is flooded for 2-3 months a year by 1-2.5 m of water, and some areas are characterised by peat soils of 0.5-4 m depth. At 40,000 years of age, these peatlands are among the oldest in Indonesia.

Dwarf swamp forest develops in areas that may be flooded by 4-5.5 m for 8-12 months per year.

Stunted swamp forest is intermediate between tall and dwarf swamp forest in terms of flooding depth and duration.

Almost two-thirds of the swamp forest is stunted swamp forest, while one-third is tall swamp forest. Dwarf swamp forest forms a minor element only.

Swamp forests are prone to fires, possibly due to the accumulation of large amounts of organic matter in the wet months, and repeated fires appear to be leading to an expansion of dwarf and stunted swamp forest, at the expense of tall swamp forest. Most fires are caused by human interventions, and have markedly increased since 1990. Herbaceous submerged and emergent aquatic herbs are rare, as the extreme fluctuation in water level limits the growth of these species.

More than 500 plant species have been recorded at DSNP; three-quarters are trees and shrubs and 262 occur in the swamp forests. DSNP harbours many novel and interesting plant species, such as *Dichilanthe borneensis,* which was collected by Beccari in 1867 and is not found elsewhere. This unique tree represents a link between the coffee family (*Rubiaceae*) and the figwort family (*Scrophulariaceae*). A new species of *Rhodoleia* collected in 1993 belongs to the witch-hazel family (*Hamamelidaceae*), a family with only seven genera in South-East Asia, each represented by only one species. Other rare species include the small tree *Dicoelia beccariana*, the sedge *Hypolytrum capitulatum,* the stemless palm *Eugeissona ambigua* and the rattan *Plectocomiopsis triquetra*.

DSNP fauna

The lakes and black waters of the swamp forests of Danau Sentarum are remarkable for their fish diversity, and 266 fish species have been identified in the Park and in smaller streams around the area since 1992, including at least 12 new to science.

The DSNP fish fauna includes two highly popular aquarium fish: the rare and valuable red variety of the endangered Asian Arowana *Scleropages formosus*, and the clown loach *Botia macracanthus,* known from only several localities in Kalimantan and Sumatra.

Three species of crocodile occur at DSNP, including the rare and endangered false gavial *Tomistoma schlegeli*, the estuarine crocodile (*Crocodylus porosus*), and an enigmatic third species (possibly *C. raninus*).

DSNP's birdlife has been relatively well studied, with 237 confirmed species – half of the species recorded on Borneo. These include nine threatened and 22 near-threatened species, including the Argus pheasant *Argusianus argus* and the Storm's stork *Ciconia episcopus stormi*. Storm's stork, which breeds in these inland swamp forests, is listed as rare and is considered to be the world's rarest stork.

The vast majority of bird species are forest-dwellers. Waterfowl are relatively rare, probably because of a lack of herbaceous aquatic vegetation cover. Colonial water birds such as egrets and herons have been wiped out due to hunting and egg collecting, and the area has probably never had many ducks or waders.

DSNP has the largest inland population of proboscis monkeys, but they are elusive, probably due to past hunting pressures, and unlike other populations of this species, they venture far from waterways frequented by fisher folk. A remarkable recent discovery is that the swamp forests and peat swamp forests around Danau Sentarum harbor what may be one of Borneo's largest populations of orang-utan.

DSNP threats

Except for colonial waterfowl, exploitation levels of various resources were fairly sustainable until about 2-3 decades ago. Since then, the resource base appears to have been steadily eroding, with fish catches declining and tall forest area dwindling. The reasons are complex, involving the influx of migrants, increased non-adherence to local customary law, population increase, increased access to external markets, and a steady development of adjacent areas (e.g. by large-scale logging and plantation companies).

Fires have become increasingly common. Recently burned areas and swamp forest regenerating after fires now account for about 20% of the Park.

The single greatest threat at present is from the development of large-scale oil palm plantations around DSNP belonging to about 20 companies and extending more than 300,000 ha. Pollutants from oil palm estates around DSNP are likely to flow into the Park's waterways and end up in swamp forests, lakes, fish and wildlife.

– Wim Giesen, Euroconsult Mott MacDonald, Arnhem, The Netherlands

Swamp forest along Danau Sentarum lake during a very dry season.
Photo: Stephan Wulffraat

Recommendations for project follow-up

This section proposes next steps, based on the work done to date.

TOP: Mount Kinabalu as seen from the west coast. Photo: Stephan Wulffraat

Biological Indicators

Some of the biological indicators could not be finished due to lack of field data and time constraints. In several cases, it was still possible to develop workable information by extrapolation of existing data and knowledge.

Table 7 shows what indicators need to be completed so that the status information for the HoB is as representative as possible:

Several suggestions for additional biological indicators were raised during meetings and discussions with colleagues, including:

1. Sun bear – another top level carnivore, easier to observe and study than the clouded leopard, with good field data already available. It is also a large carnivore but with a completely different feeding ecology. Sun bears can survive in large secondary forests and slightly disturbed areas. Hunting pressure is higher than on clouded leopard because there is a market for gall bladders and bears are easier to encounter. However data collection requires significant efforts.
2. The Proboscis monkey (and possibly the False Gavial) might be a good indicator for conditions of peat swamp, mangrove and wide riparian forests, but these ecosystems have very restricted ranges inside the HoB boundaries.
3. Endangered fish species such as Arawana get a lot of attention but this is more about over-harvesting.
4. Other endangered plant species: So far we have concentrated on endemic Nepenthaceae, but other families, including Fagaceae, Dipterocarpaceae, and other plant groups such as certain Orchid taxa should be evaluated. A selection should be made on which species are vulnerable to what threat.
5. Hornbills: Certain species of hornbill, notably the helmeted hornbill, are good indicators of forest conditions. Information on these hornbills can be obtained through interviews of local communities, but only on a local scale.
6. The straw-headed bulbul is severely affected by (illegal) trade and has become locally extinct in several areas.

7. Gibbons might be good indicators for forest conditions as they are mainly found in tall primary and old secondary forests. However information on gibbons can only be obtained at a local scale.
8. Pangolins: It would be very useful to include a species that can be used as an indicator for specific hunting, for example pangolins, which have been hunted to near extinction for the medicine trade (E. Meijaard, pers. comm.).

Threat indicators

Threat indicators are very important, but our data on these issues is still limited. Further efforts (through counterparts) are needed to obtain data from Malaysia (including Sabah but particularly Sarawak) and Brunei. During the threat analysis, mining turned out to be a more pressing issue than originally assumed, and mining concessions data should become available at least from Indonesia. Some forest conversion indicators can be obtained by further analysis of remote sensing data. Very localised threats such as over-hunting and illegal logging can only be evaluated with comprehensive data sets from the field.

Conservation management indicators

Several conservation management initiatives for the Heart of Borneo have only started recently. The indicators will be very important to measure impacts of conservation work and will be investigated as soon as further developments are made.

'Cross cutting' issues

Protocols for the frequency of collection for each indicator need to be worked out. For some data this would be annually, while for other data every 2-5 years might suffice.

It is our aim to hire local monitoring officers, at least one for each Kalimantan province, but particularly for Malaysia, where data collection has been challenging.

In addition to the questions about specific indicators noted above, the monitoring working group will be continuing to add additional documentation on where the data was collected. Methods will be developed to integrate biological and socio-economic indicators.

Table 7. Status of difficult biological indicators in the HoB.

Target	Indicator	Comments
Heath forest ecosystems	% historical remaining	Small areas of heath forests have never been mapped. Occurrence of heath forest is strongly related to specific geo-morphological and soil characteristics which have been mapped to a more detailed level. This can to a certain extent be used to map smaller areas of heath forest.
Limestone forest ecosystems	% historical remaining	Small areas not currently mapped using 250 m resolution remote sensing imagery. This information is particularly important for unique ecosystems that are often not large in extent. These areas can be mapped by analyzing the REPPPROT Land System maps. Information on collection of edible bird nests from caves will also be helpful because these caves are usually found in limestone areas.
River ecosystems	Fish species diversity	Fish survey reports exist for several major rivers of Borneo but more time is needed to compile these and to prepare a data format that can be used as an indicator.
Bornean orang-utan	1. Densities in peat swamp 2. Densities in lowland rainforest	More data will become available with ongoing orang-utan research throughout Borneo, such as the OSCP interview based orang-utan survey.
Sumatran rhinoceros	1. Population size	Species on verge of extinction: in Sabah only; wild rhinos are no longer adequate to sustain the species.
Banteng	1. Presence in known sites	We have the most important banteng locations for Borneo. However, extrapolation of habitat information (as for the clouded leopard) will not work well with this species. Relatively open areas of abandoned cultivation might be an indicator.
Bearded pigs	1. Presence of large numbers at representative sites 2. Group size at representative sites 3. Fat condition at representative sites	Information from research projects could give us better insights to predict large numbers of pigs in Borneo, and in certain areas even predict mass movements. Large numbers might only be recognised in mast fruiting years. Over-hunting and fat condition are very localised issues.
Endangered plant species	% of viable historic locations	This will also be done for other endangered plant species on the IUCN Red List; unfortunately distribution data is often very limited.

Table 8: Status of difficult threat indicators in the HoB.

Threat	Indicator	Comments
Industrial conversion of natural forests	Areas (km^2) planned for clearing Areas (km^2) planned for logging	This information should officially be included in the provincial land use planning but is in reality not easily available.
Illegal logging	Areas (km^2) affected by illegal logging	Only few official records are made available. Police records should be monitored.
Legal commercial but unsustainable rates of timber extraction	% of crown cover in production forests	This data can only come from concession holders, who are naturally not willing to provide this.
Mining	Existing extent and projected extent	The Ministry of Mining has not yet published an official mining concessions map. Mining data should be complemented with information from districts.
Conversion of forest through small-scale agriculture	Areas and locations of annual conversion	Forest cover time series with higher resolutions are needed, combined with spatial information on settlements and agriculture.
Direct impacts of road Construction	Areas of forest conversion along new roads	Satellite images with higher resolution (than the current 250 m) are needed.
Expansion of hydropower dams	% of major rivers obstructed	Satellite images with higher resolution (than the current 250 m) are needed.
Recent extreme droughts	Areas affected by extreme droughts; length of periods in between droughts	No protocol developed yet to measure this.
Unsustainable firewood extraction	Areas of forest destruction caused by over-harvest	Forest cover time series with higher resolutions are needed, combined with spatial information on settlements.
Over-hunting and collecting	Areas with animal populations strongly declining Areas (km^2) effected by over-hunting	This information can only be collected through long-term biological research, something which has been done in only a few places in Borneo, and these were mainly protected areas. Perceptions of population trends from local communities will be useful.

Table 9: Status of difficult conservation management indicators in the HoB.

Conservation management	Indicator	Comments
Proposed protected areas	km^2 of proposed protected areas by habitat	HoB initiatives for proposing corridors with sustainable land use and protected status are still in an early stage and cannot yet be measured.
Protected area effectiveness	RAPPAM (Ervin 2003) score	Indications of effectiveness through scoring designated by officers working in protected areas is currently being compiled
Regeneration in protected areas	Regeneration Post HoB	Areas with significant re-growth of natural vegetation. This requires more detailed images and ground-truthing.

BELOW: Rapids in the Agison river in East Kalimantan, close to Sabah. Photo: Andris Salo

Putting the HoB on the map

HISTORICAL AND CURRENT EXTENT

Lowland rainforest ecosystems

Lowland rainforest ecosystems are on dry land less than 300 m above sea level (asl) with common soil substrates (clay, loam, sand, etc). This ecosystem is relatively limited within the HoB, which encompasses mainly the higher upstream areas of Borneo. Forests on limestone soils are in a separate ecosystem, as are heath forests, which grow on extremely poor and usually white sandy soils.

Lowland rainforests reach their highest diversity below 200 m, in both species richness and structural development. In most areas, they are dominated by trees of the Dipterocarpaceae family, which is why they are usually called lowland Dipterocarp forests. However, species composition varies significantly for different locations, e.g. ironwood trees (*Eusideroxylon zwageri*) can be dominant in some areas.

The tallest trees in Borneo are found in this ecosystem, reaching heights of up to 70 m.

The eastern part of Sabah had large stretches of lowland rainforest but many have been converted to oil palm plantations. There are good forests remaining, some in primary condition, particularly in the upper Kinabatangan and Segama watersheds.

Most of the upstream areas of Brunei were included in the HoB and, given the rather low elevations, most of these areas are covered with lowland rainforests. The Brunei government is very serious about watershed protection and hardly any of these forests have been converted.

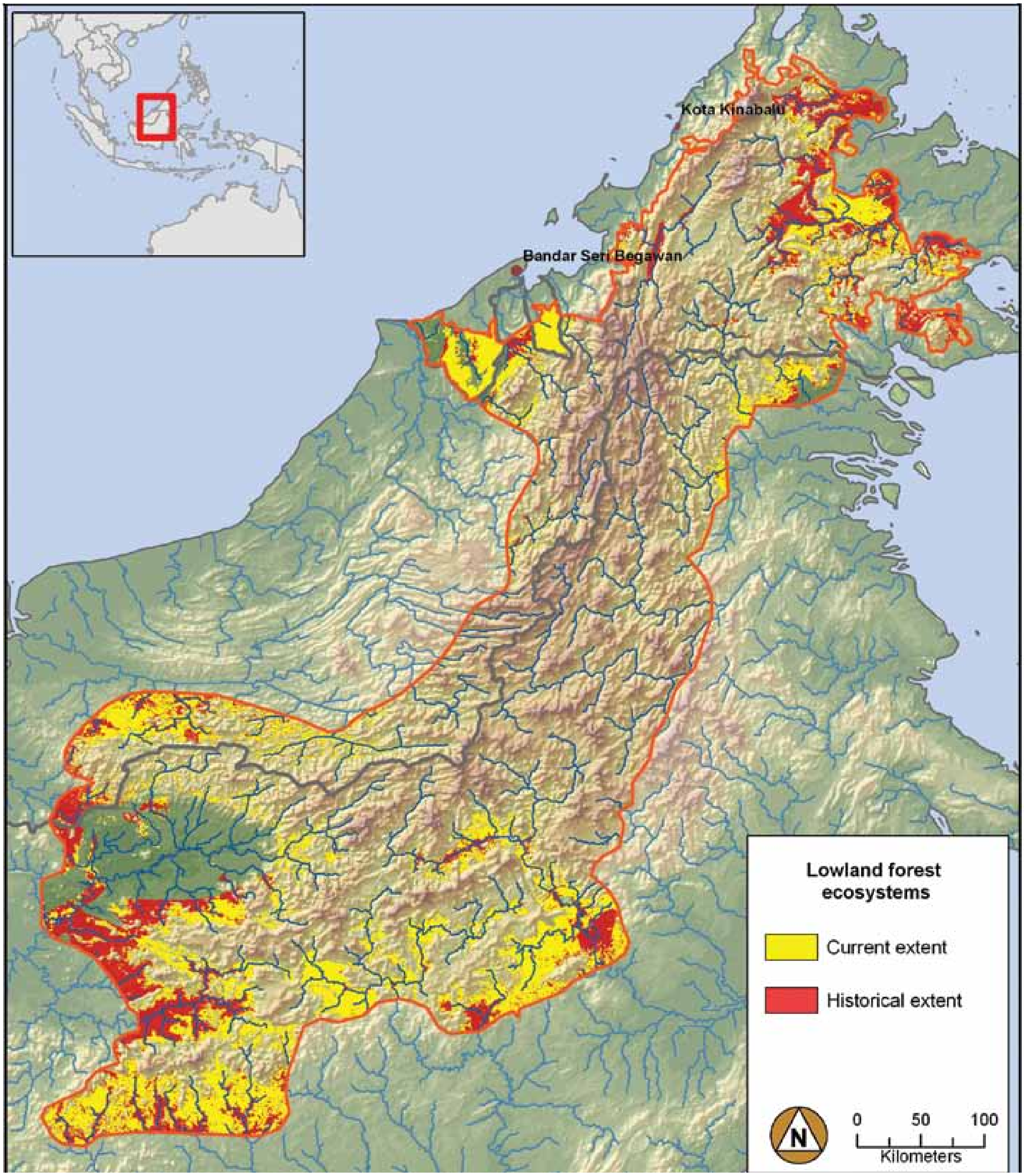
Lowland rainforests within the HoB boundaries of Sarawak are found mainly in the upper Baleh and Rajang drainage areas, on the foot slopes and valleys of the mountain range that forms most of the border area. Most of these forests are in logging concessions and little has been converted so far.

Most of the HoB areas of East Kalimantan are uplands and mountains. Small lowland rainforests are found in the Malinau and Nunukan districts, with more extensive areas in the upper Mahakam. Many are under logging concessions or are in secondary condition, with conversion for oil palm plantations and small-scale agriculture, often in the form of shifting cultivation.

Central Kalimantan has the largest area of lowland rainforest within the HoB. There are still extensive areas along the foot slopes and in the wide river valleys south of the Bukit Baka-Bukit Raya mountain range. However, most of these forests have been logged and some are being converted, mainly for agriculture. The upper drainage area of the upper Barito river and its many tributaries has several lowland rainforest areas. Most have been logged and some logging concessions are still active. A few areas have so far been left untouched, and are some of the best primary lowland rainforest in Kalimantan.

Most of the lowland rainforests of West Kalimantan have been converted and even within the HoB only a few were spared. These are mainly small areas around Danau Sentarum that are not peat swamps, lowland areas of the upper Melawi and small areas north of the Bukit Baka-Bukit Raya mountain range.

Primary lowland forest with big Dipterocarpus lowii tree. Murung Raya, Central Kalimantan. Photo: Stephan Wulffraat


Kota Kinabalu
Bandar Seri Begawan
Lowland forest ecosystems
Current extent
Historical extent
N
0
50
100
Kilometers

STATUS

Lowland rainforest ecosystems

Most of the remaining lowland rainforests of West and Central Kalimantan are in logging concessions. The large lowland rainforest area of Arut Belatikan and Rongga Perai might be retained as many of the logging companies working in this area are committed to sustainable timber production.

A large part of the lowland rainforests of the Melawi River drainage area is being converted in West Kalimantan.

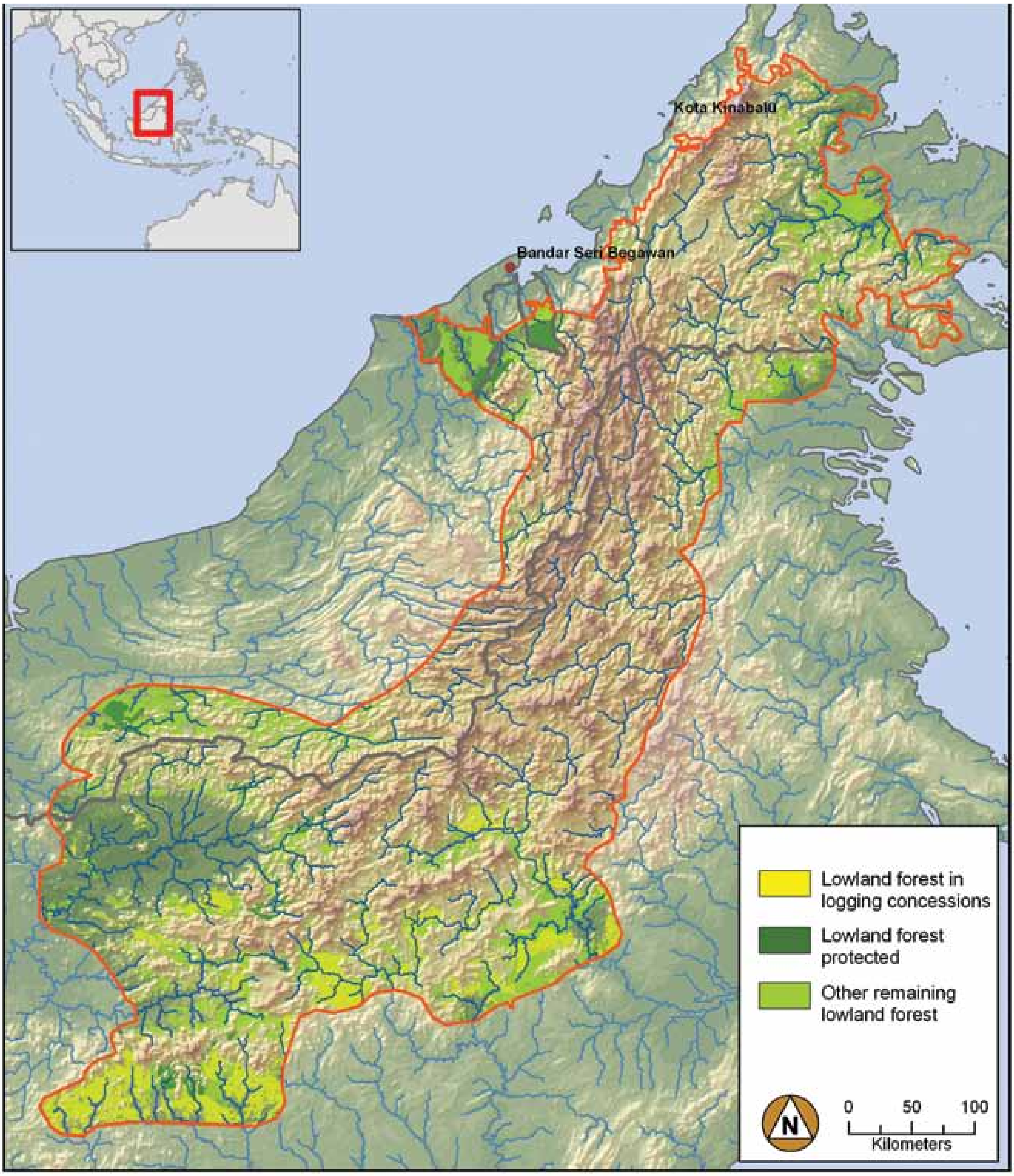
The upper Katingan River area in Central Kalimantan has so far not been designated for conversion. Several lowland rainforest areas of the upper Barito (Joloi, Murung, Busang, Maruwai) are being considered as suitable habitats for re-establishing orang-utan populations. Opportunities exist for Restoration Concessions or developing orang-utan management plans with concession holders.

The lowland rainforests of East Kalimantan are mainly located in Nunukan district. Part of these are threatened with conversion.

There is no clear information for the status of the HoB lowlands of Sarawak, but indications are that most of the remaining lowland forests are in logging concessions. Lanjak Entimau Wildlife Sanctuary and Batang Ai National Park have some good areas of lowland rainforests that are thus protected.

Most of the lowland rainforest ecosystems of Brunei that are within the HoB are protected.

The remaining lowland rainforests of Sabah within the HoB are classified as Forest Reserves. Most of these are Commercial Forest, for timber production. Parts of it, such as the Danum Valley Conservation Area, are protected from logging.



OPPOSITE: Side view of the canopy of primary lowland forest. Murung Raya, Central Kalimantan. Photo: Stephan Wulffraat

HISTORICAL AND CURRENT EXTENT

Upland rainforest ecosystems

Upland rainforests make up the largest HoB ecosystem, with a total area of almost 7.5 million hectares. They grow on common soils at elevations of 300 m to 800 m above sea level, reflecting reasonable average ecological situations. In certain conditions, for instance very fertile and deep soils, upland rainforest types grow higher than 800 m, but on terrain with very steep slopes and shallow soils they might not reach this elevation.

Dipterocarpaceae species are the important components of the vegetation composition, but are not as dominant as in most of the lowland rainforests. Nevertheless, upland rainforests are often referred to as 'Hill Dipterocarp forests'. Large trees from other families are more common here than in lowland rainforests. Sapotaceae, Burseraceae and Lauraceae can be important components of the canopy. Giant *Ficus* trees are most commonly found in upland rainforests. Pulpy fruit-producing species such as *Artocarpus*, *Durio* and many Sapindaceae are more common in lowland rainforests, which is one of the reasons that orang-utans prefer the lowland habitats. The proportion of Fagaceae and Myrtaceae gradually becomes higher with increasing elevations.

The vegetation structure of upland rainforests is less complex and diverse than in lowland rainforests. Emergent trees are less prominent, making the canopy look more homogenous, and large buttresses are not as common as in lowland rainforests.

Most of the upland rainforests of the HoB still exist. The higher elevations and usually steeper slopes make these areas less suitable for developing oil palm plantations. Plantations in uplands are only established where lowlands are not available (anymore). Upland rainforests have lower volumes of commercial timber than lowland rainforests but, with high timber demand, logging of these forests is still highly profitable.

The highest conversion of upland rainforests has occurred in Sabah, particularly for pulp wood plantations.

Sarawak has large stretches of upland rainforests in its interior area included in the HoB. Most are under logging concessions but will probably not be converted. Small-scale conversions visible on the map are mainly caused by shifting cultivation agriculture and the numerous log ponds and timber camps.

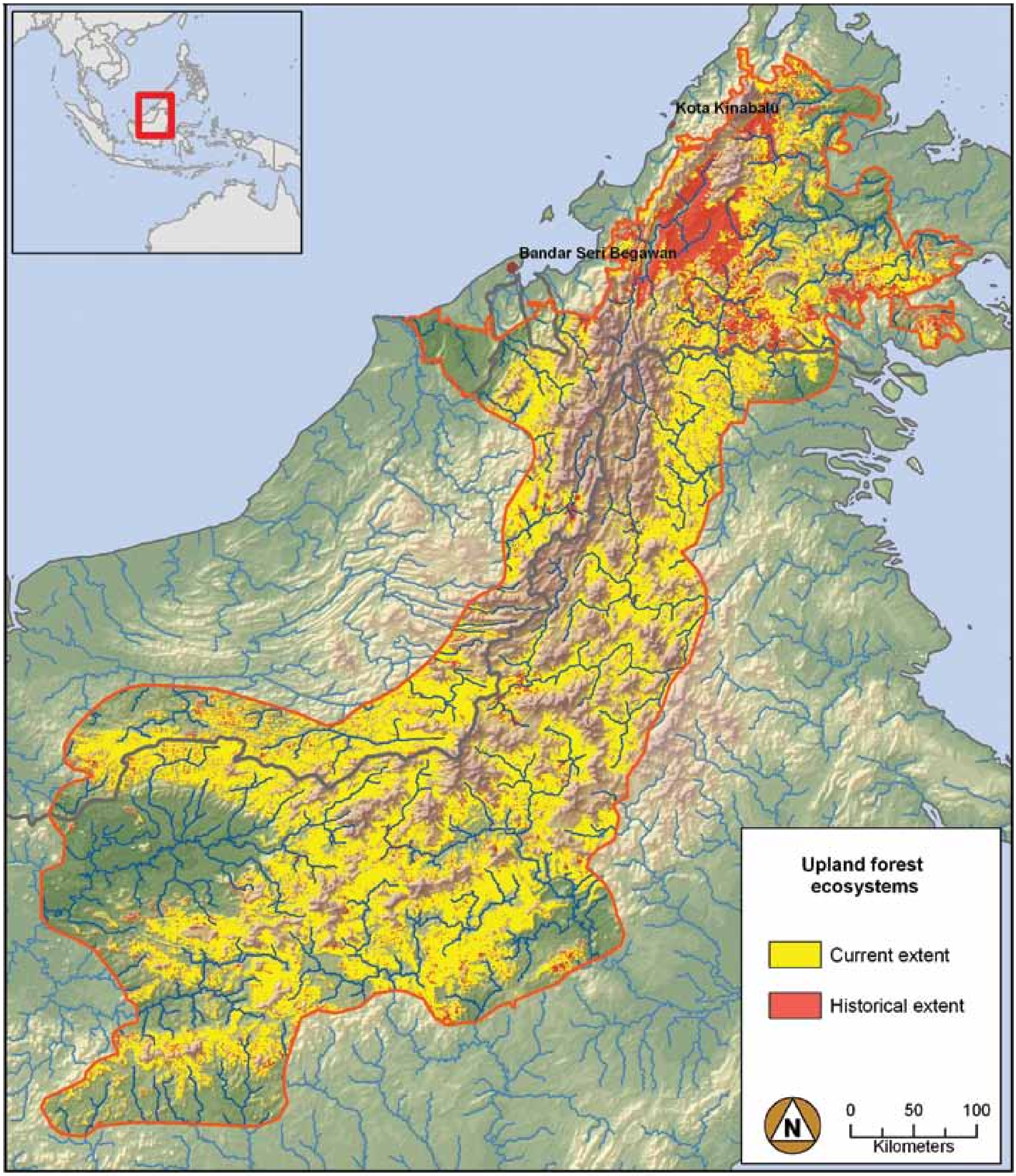
East Kalimantan is covered by large and often continuous stretches of upland rainforests. Logging of the Mahakam drainage area has been going on since the 1990s but started later in the northern part of the province. Most locations along the major rivers have been used at one time for shifting cultivation agriculture and small scale logging by local communities. Upland rainforests in the more remote locations are frequently still in near-primary conditions.

The largest part of the northern section of Central Kalimantan is below 800 m asl and is covered by upland rainforests. Most have been logged or are currently under logging concessions. Upland rainforests at the foot slopes of the mountains are generally still in pristine conditions. Coal mining could become a threat to many of the upland rainforests of Central Kalimantan, including those that are originally not designated for conversion.

The largest stretches of upland rainforests in West Kalimantan are inside the Betung Kerihun National Park. Many of the other upland rainforests here are not in pristine conditions.

Upland conversions in West, Central and East Kalimantan are mainly for small-scale local agriculture.

Waterfall over various layers of sedimentary geological substrates in upland forest, Central Kalimantan. Photo: Stephan Wulffraat


Kota Kinabalu
Bandar Seri Begawan
Upland forest ecosystems
Current extent
Historical extent
N
0
50
100
Kilometers

STATUS

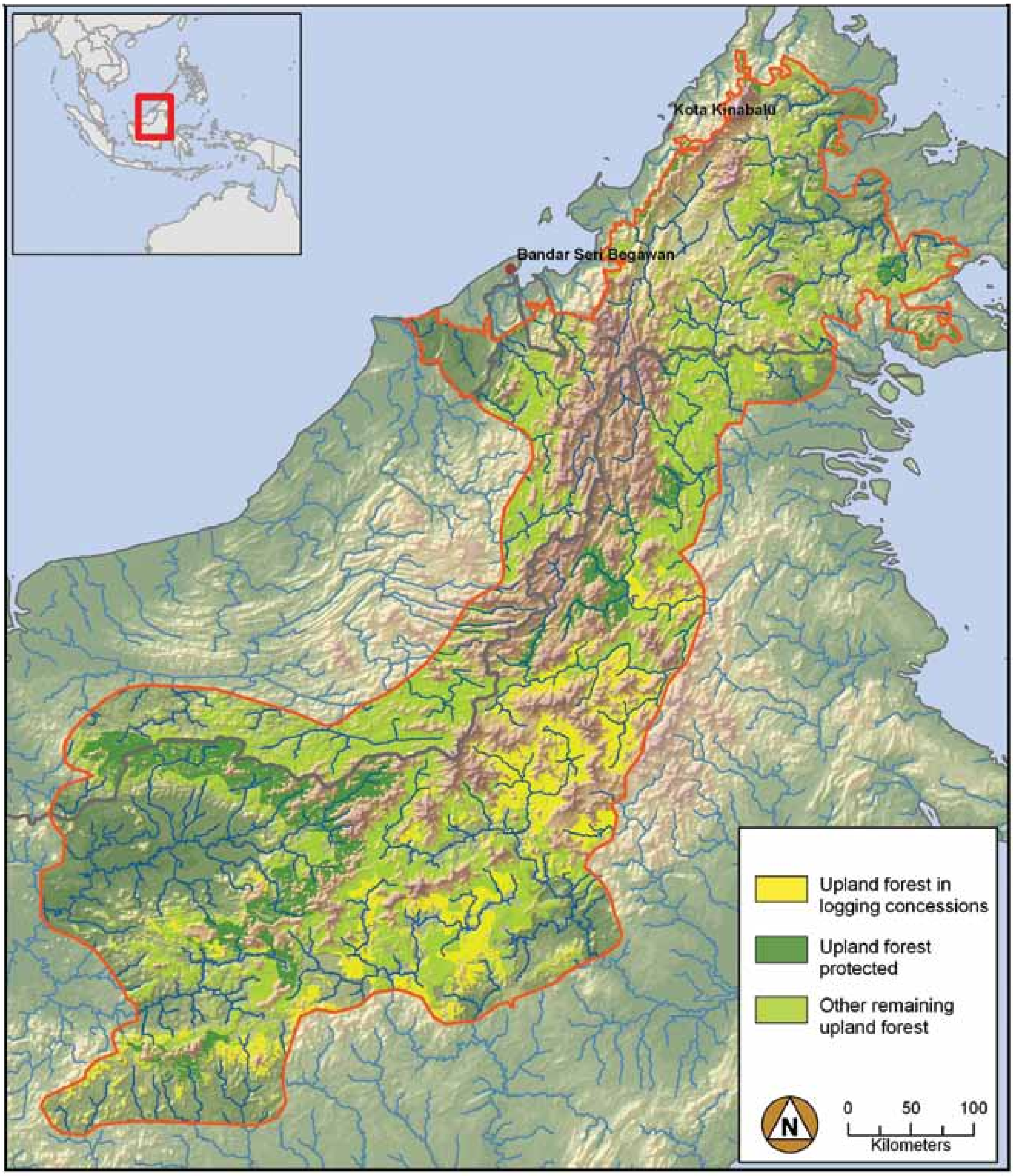
Upland rainforest ecosystems

Part of the upland rainforests of West but particularly Central and East Kalimantan are under logging concessions. Incentives for sustainable timber production are generally stronger in these upland concessions, since the land is often less suitable for plantations.

The largest areas of protected upland rainforests are in the Betung Kerihun and Kayan Mentarang National Parks.

Large stretches of upland rainforests still exist in the Heart of Borneo and most of these are still connected. It is a major objective for the survival of the HoB to ensure that these areas remain forested with a vegetation structure as natural as possible, either with a protected status or at least through sustainable management strategies.

Primary upland rainforest in Murung Raya, Central Kalimantan.
Photo: Stephan Wulffraat


Kota Kinabalu
Bandar Seri Begawan
Upland forest in logging concessions
Upland forest protected
Other remaining upland forest
N
0 50 100
Kilometers

HISTORICAL AND CURRENT EXTENT

Montane forest ecosystems

Most of Borneo's montane areas are within the HoB, with the almost 3.5 million hectares of montane forest ecosystems making up about one sixth of the total area.

All forests higher than 800 m above sea level (asl) are considered montane forests for our analysis. The transition from upland to montane forest occurs gradually. In conditions with poor soils, this boundary can be as low as 600 m asl.

The most common forest type of the lower montane zone in Borneo is Oak-Myrtle forest, at least partly dominated by trees of the Fagaceae and Myrtaceae families. The genus *Syzygium* is usually represented by tens of different species, while the smooth orange or greyish boles trees of the genus *Tristaniopsis* (also Myrt.) are conspicuous. Other typically important families include Guttiferae, Theaceae and Lauraceae. Dipterocarpaceae are rarely seen anymore, but in certain montane locations with deep soils, such as foot slopes and alluvial valleys, they can still be the (co-)dominant family. This forest type is often referred to as Upper Dipterocarp Forest.

A remarkable aspect of Borneo's montane zones is the forest vegetation on the ridges dominated by *Shorea curtisii* and *Agathis borneensis*, which often grow into large trees.

The vegetation structure of lower montane forests is generally a regular tall forest, with a rather open under-storey and nondescript tree densities. Large buttresses on trees are rare.

The upper montane zone starts at about 1,500 m. The trees of upper montane forests remain low, and rarely reach more than 50 cm in diameter. The stems are often gnarled or bent, particularly along exposed summits. The lower boles are often covered with mosses and the forest type is sometimes referred to as Moss Forest.

Fagaceae and Myrtaceae are the most common plant families of the upper montane zone. Theaceae species such as *Gordonia* and *Schima* can be locally abundant. Remarkable plant species such as endemic pitcher plants and orchids are often found in this zone.

There are specific types of montane forest more correlated to soil conditions than to elevations: montane peat swamp forests, montane limestone forest and montane heath forests. For our purpose, they are too small to be distinguished within montane areas and could not be mapped separately.

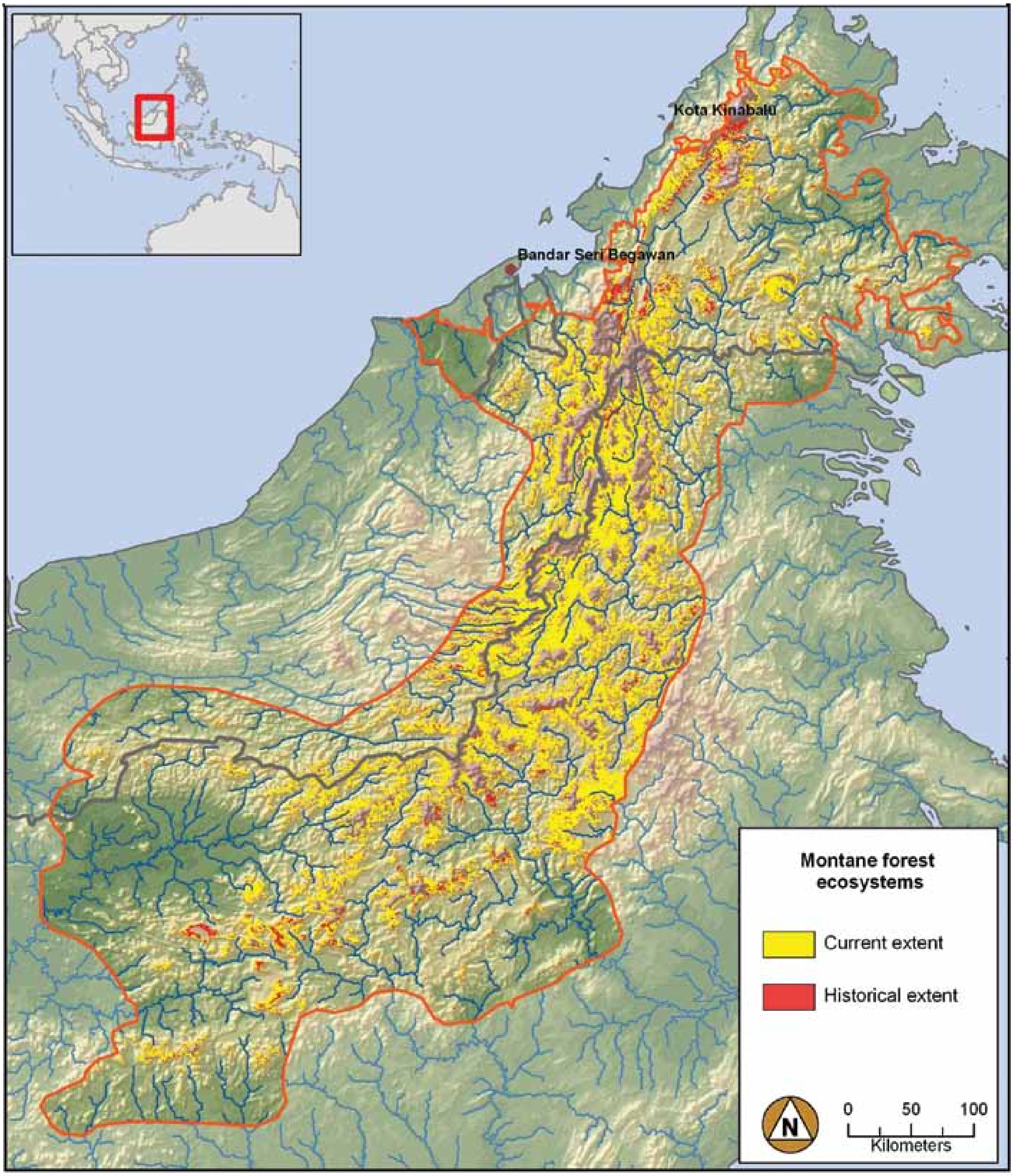
The few montane areas outside the HoB are mainly the Meratus mountains in South Kalimantan and Gunung Niut and some other non-connected mountains in West Kalimantan.

The montane areas of the HoB are generally in very good condition. Many have a protected status and less than 12% has been converted so far. The largest conversions are along the slopes of the Mt Kinabalu complex. These areas are suitable for the cultivation of vegetables.

In West and Central Kalimantan a number of montane areas are used for open pit coal mining, which involves all vegetation being removed first.

Shifting cultivation is not commonly practised in montane areas. One of the few areas where this happens is in the Krayan areas of East Kalimantan, a highland plateau partly below 700 m asl.

Small spots of deforestation can be found throughout the montane areas of Borneo. These are usually the result of landslides or local fires caused by lightning and the vegetation will slowly recover here.


Kota Kinabalu
Bandar Seri Begawan
Montane forest ecosystems
Current extent
Historical extent
N
0
50
100
Kilometers

STATUS

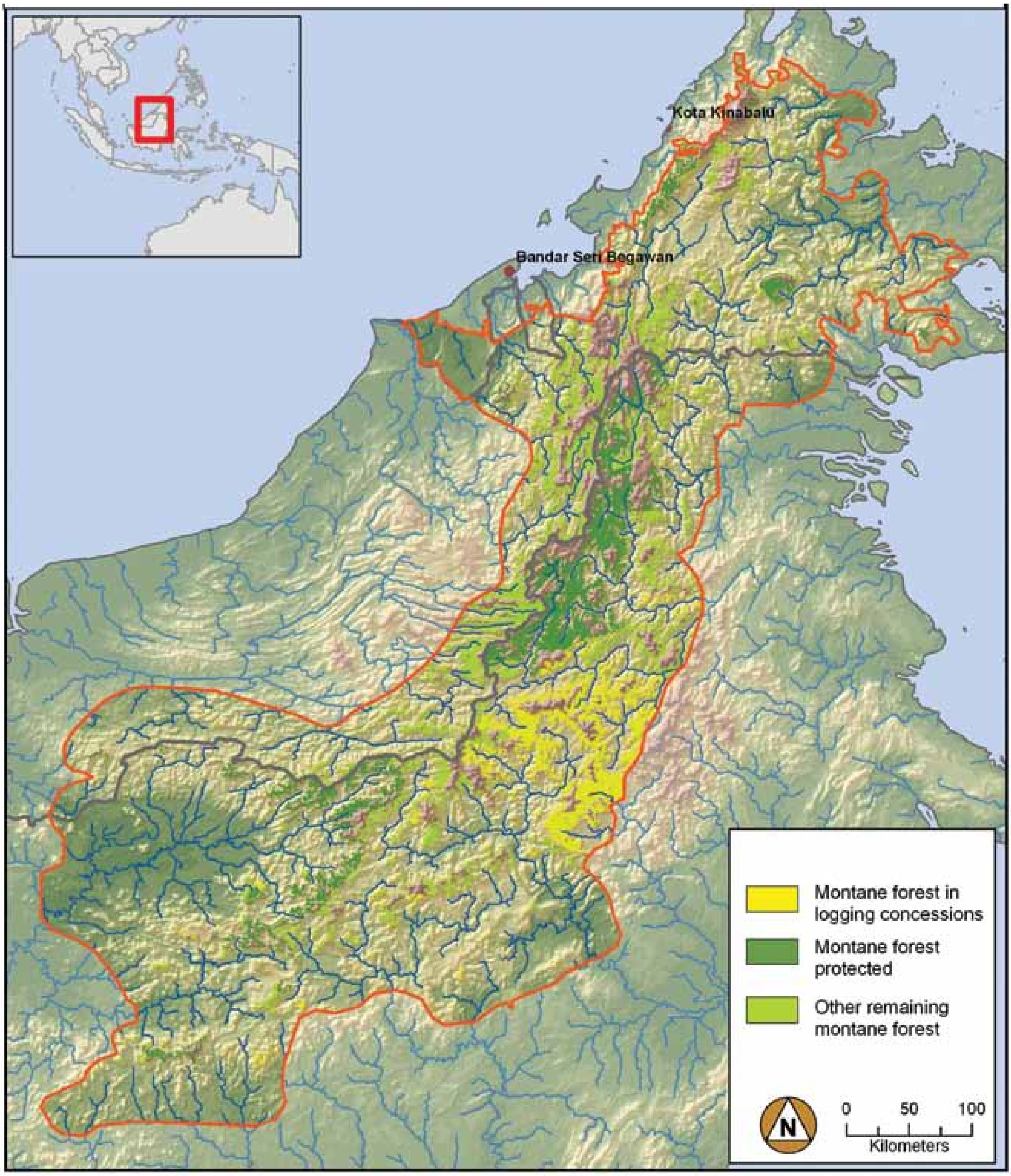
Montane forest ecosystems

Most of the montane forest ecosystems at elevations above 1000 m above sea level are protected. The lower slopes of these mountain complexes comprise a substantial total area and many of these are not protected. Nearly all of the montane forests under logging concessions are situated in East Kalimantan. All of these are concessions that are made up of mainly lowland and upland rainforests, with only (small) parts of montane forests.

The commercial value of these montane forests depends on the local geomorphology. Slopes with the common montane Oak-Myrtle forest have few species for commercial interest. Certain ridges, however, covered by montane ridge forest with large *Agathis* and *Shorea* trees, will almost certainly be logged.

The protection of all montane ecosystems of the Heart of Borneo will be of major importance to the continuation of healthy watershed functions.

Upper montane forest in east Kalimantan. Photo: Stephan Wulffraat


Kota Kinabalu
Bandar Seri Begawan
Montane forest in logging concessions
Montane forest protected
Other remaining montane forest
N
0
50
100
Kilometers

HISTORICAL AND CURRENT EXTENT

Peat swamp ecosystems

Borneo has extensive areas of peat swamp ecosystems, especially in West and Central Kalimantan.

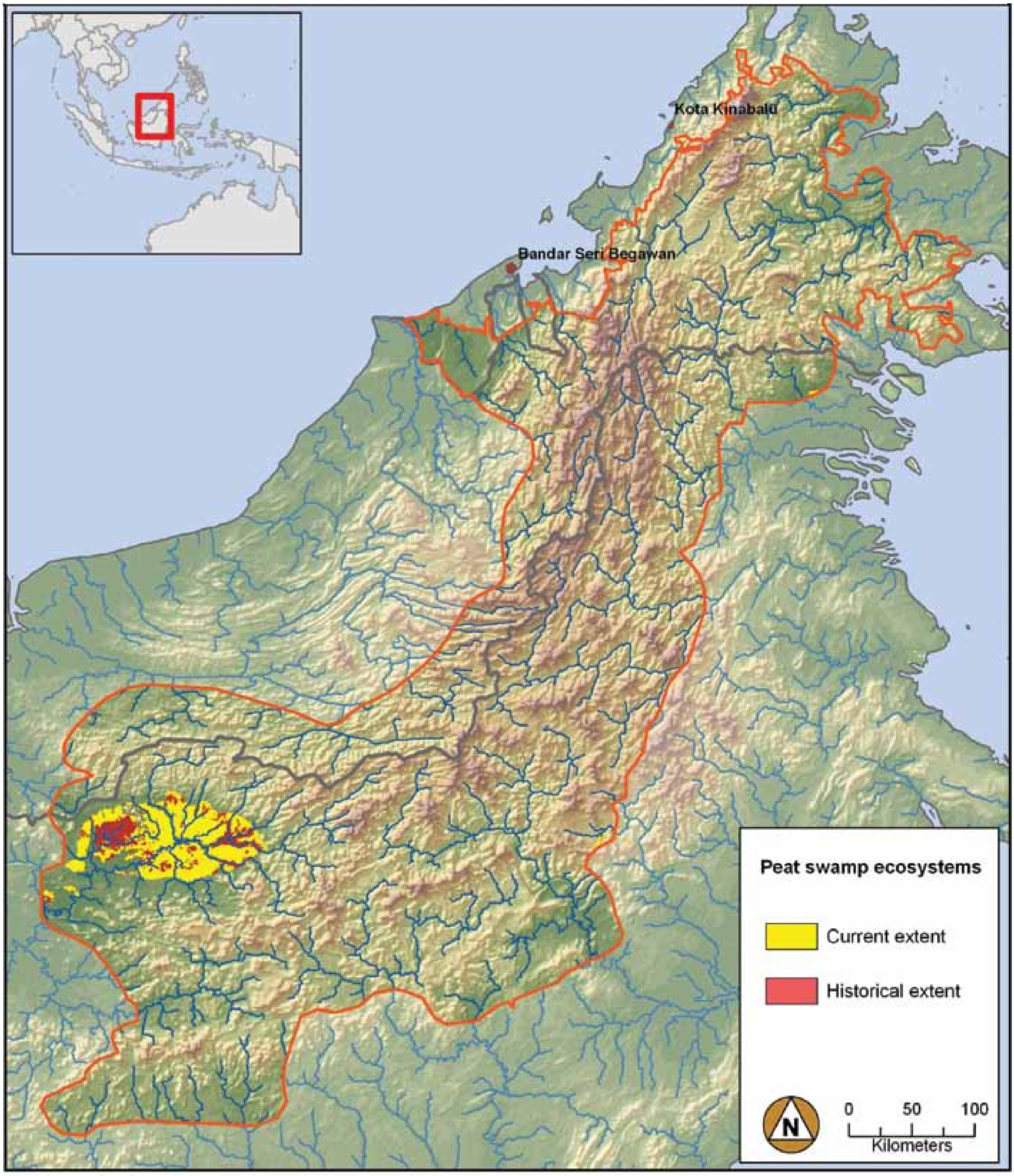
Peat swamps occur mainly in flat lowland areas such as the coastal plains which in parts of Borneo stretch for tens to hundreds of kilometres inland. However, this ecosystem is not very common in the interior HoB, where most of the terrain is undulating, hilly or mountainous.

The largest stretches of interior peat swamp forests are in the flat lowland basins around the lakes of the middle courses of the Mahakam River in East Kalimantan and the Kapuas River of West Kalimantan.

The middle Mahakam lake area is outside the HoB boundaries. The lake area of the Kapuas, commonly known as Danau Sentarum, is part of the HoB. The area consists of several lakes that are surrounded by wide flood plains. In most of these plains peat swamps developed through thousands of years of accumulation of organic materials. Forest growing on these peats is very diverse, with several different vegetation types.

These peat swamps are inundated for several months each year. Conversion of the forests is complicated because of this inundation regime, which is why a relatively large extent is still present.

Swamp forest inundated by muddy water, East Kalimantan.
Photo: Stephan Wulffraat


Kota Kinabalu
Bandar Seri Begawan
Peat swamp ecosystems
Current extent
Historical extent
N
0
50
100
Kilometers

HISTORICAL AND CURRENT EXTENT

Limestone forest ecosystems

Limestone forest ecosystems have developed in a thin layer of organic soil, with some mineral soil, on top of base rocks of limestone. While naturally rich in calcium, these soils are poor in a number of other important minerals. Exposed rocks are commonly seen at summit crests and very steep slopes.

The vegetation is unique in both composition and structure. Trees are often stunted and have extensive semi-surface root systems to optimise their opportunities for nutrient intake in the shallow soils. This ecosystem is particularly rich in herbaceous plants, many found only on limestone soils, and a large number of unique invertebrate species.

Limestone formations often have remarkable shapes evolved through ages of erosion: strange peaks, sharp ridges, high cliffs and escarpments and the irregular drainage of these locations frequently create waterfalls. Caves within these formations are used as nesting sites by the Collocalia spp. swiftlets. These birds produce edible nests that fetch high prices on international markets. Even the most remote caves with reasonably large numbers of birds are exploited for this business.

The map opposite shows only the larger limestone forest areas in the HoB. There are many small limestone outcrops that could not be mapped at this stage.

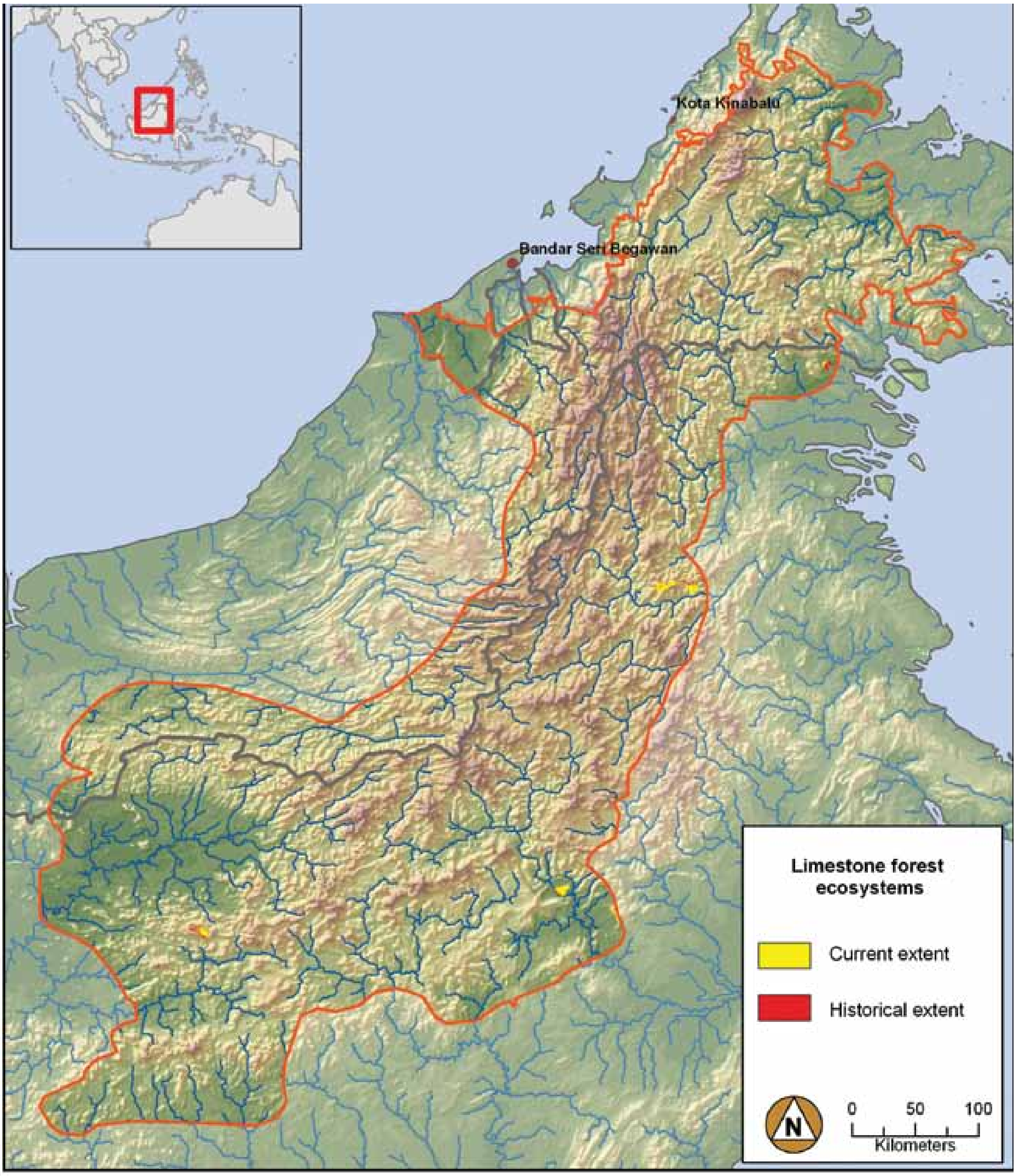
One of the largest and definitely the best known limestone forest areas is in the Gunung Mulu National Park in Sarawak. The Batu Mayo hills in the very north of East Kalimantan stand out in a landscape of flat to undulating lowlands. Wide stretches of limestone forest areas, often with high cliffs, are found along the Kayan and Mahakam rivers. West Kalimantan also has a number of larger limestone formations.

The largest stretches of limestone forest ecosystem of Borneo are at the Sangkuliran peninsula, which is outside the HoB.

Limestone ecosystems are very sensitive to disturbances because their shallow soils are easily washed away once the plant roots that are keeping it together are removed.

Direct conversion of limestone forests is generally not a major threat, as terrains are often too steep or have too many holes, and the soils are usually not suitable for agriculture. However, indirect deforestation is common, often by people working in bird nest caves or nearby villages collecting timber and firewood. Local fires can also cause almost irreversible damage.

Since most of these habitats are small it is important to keep conversion under control.



OPPOSITE: Ficus trees growing on limestone outcrops, East Kalimantan. Photo: Stephan Wulffraat

HISTORICAL AND CURRENT EXTENT

Heath forest ecosystems

Heath forest is generally associated with white sandy soils, mainly on sandstone plateaus. These can be thousands of hectares but small areas are found throughout Borneo where the base soil material at the surface is sedimentary sandstone. Most of the organic material from leaves and wood composts at the surface, creating a thick layer of very acidic humus; water draining from heath forests is characteristically tea-coloured.

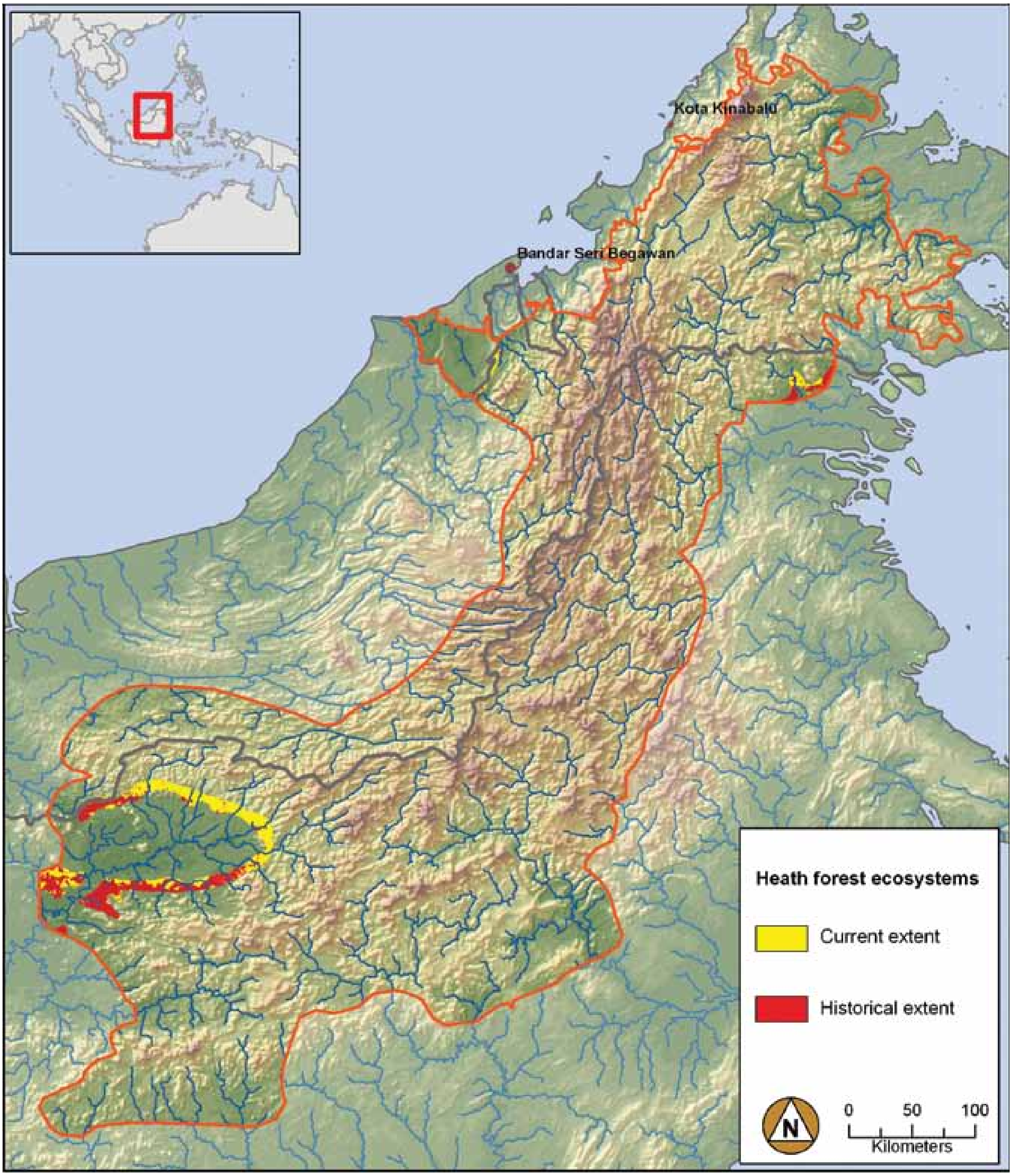
Heath forest has a distinct vegetation structure and composition, well adapted to the soil conditions. The structure is usually dense, with many small trees (with diameters below 15 cm) and a rather homogenous canopy. Many tree species have leathery and rather small leaves. Usually, *Nepenthes* pitcher plants are present in the under-storey.

The appearance of heath forest varies with terrain conditions. Where soils are better developed, the heath forest does not differ much from the surrounding lowland or upland rainforest. In the most extreme conditions, where there is hardly any soil on top of the base rocks, the higher vegetation consists mainly of shrubs and a few low trees.

Various types of heath forest can be distinguished based on elevation range and drainage. Montane heath forest, for instance, often has a proportionally large basal area of Agathis and other conifers, while frequently flooded heath forest has a very high number of shrubs.

The numerous small areas of heath forest in the HoB were not possible to map due to scale compatibility. Many small areas are known in Kayan Mentarang National Park and other parts of the interior of East Kalimantan. The hills and mountains of the upper Barito area in Central Kalimantan have small plateaus. Most of these locations are in pristine conditions.

The largest heath forest areas in the HoB are in Nunukan district (parts of which have been converted to pulp wood plantations) and on the drylands around Danau Sentarum. The latter are on the somewhat higher sandstone plateaus at some distance from the lakes. Most of the southern areas have disappeared while the northern parts are often disturbed by small-scale logging and forest fires.



OPPOSITE: High heath forest with tall Palaquium tree. Murung Raya, Central Kalimantan. Photo: Stephan Wulffraat

PERCENTAGE FORESTED WATERSHEDS

River ecosystems

Most of Borneo's major rivers arise in the interior mountain ranges that make up the Heart of Borneo. Several form very extensive systems with many tributaries and encompass drainage areas of millions of hectares.

The Kapuas river that drains most of West Kalimantan rises from the slopes of Mt Cemaru and Mt Kerihun. A southern branch of almost the same length, the Melawi river, rises in the Bukit Baka-Bukit Raya mountain range. Most of the upper drainage area is still under good forest cover. The lower range, however, is strongly deforested as a result of industrial agriculture.

The Pembuang river rises in the southern slopes of the same mountain range and flows to the south through an area with many oil palm plantation developments. The drainage area of the Katingan, further to the east, is in better condition, with both upper mountains and hills as well as lower peat swamp areas under forest cover.

The entire northern part of the province of Central Kalimantan is drained by the Barito river. The upper section of this river is usually called the Murung river, and the naming of this area as 'Murung Raya' seems a good choice. Most of this hilly area is still covered with forests, though most have been logged. The lower section of the Barito is rapidly being developed for plantations and mining.

The Makakam river, in the east, is as impressive as the Kapuas river in the west, arising from the same central Borneo mountain range. The Mahakam has a number of long tributaries, such as the Belayan and the Telen, which flow southward into the Mahakam downstream of the lakes. The mountainous upstream areas are forested, though most have been logged. The middle and lower drainage area suffered from forest fires and has largely been deforested by agriculture.

Both Kayan as well as Sesayap watersheds are generally still in good condition. The upper sections are protected as a national park (Kayan Mentarang), while the middle and lower areas are still forested with many active logging companies.

The Sembakung and the Sebuku are the only two rivers where the water divide is not recognised as an international boundary. The uppermost sections of the watersheds are in Sabah, while the rest are in East Kalimantan. The Sabah sections are (production) forest reserves, while in the Indonesian side free enterprise reigns.

Most of the interior of Sabah is still under forest cover, either as commercial forest reserves or as protected areas. Most of the lowland rainforests have however been converted.

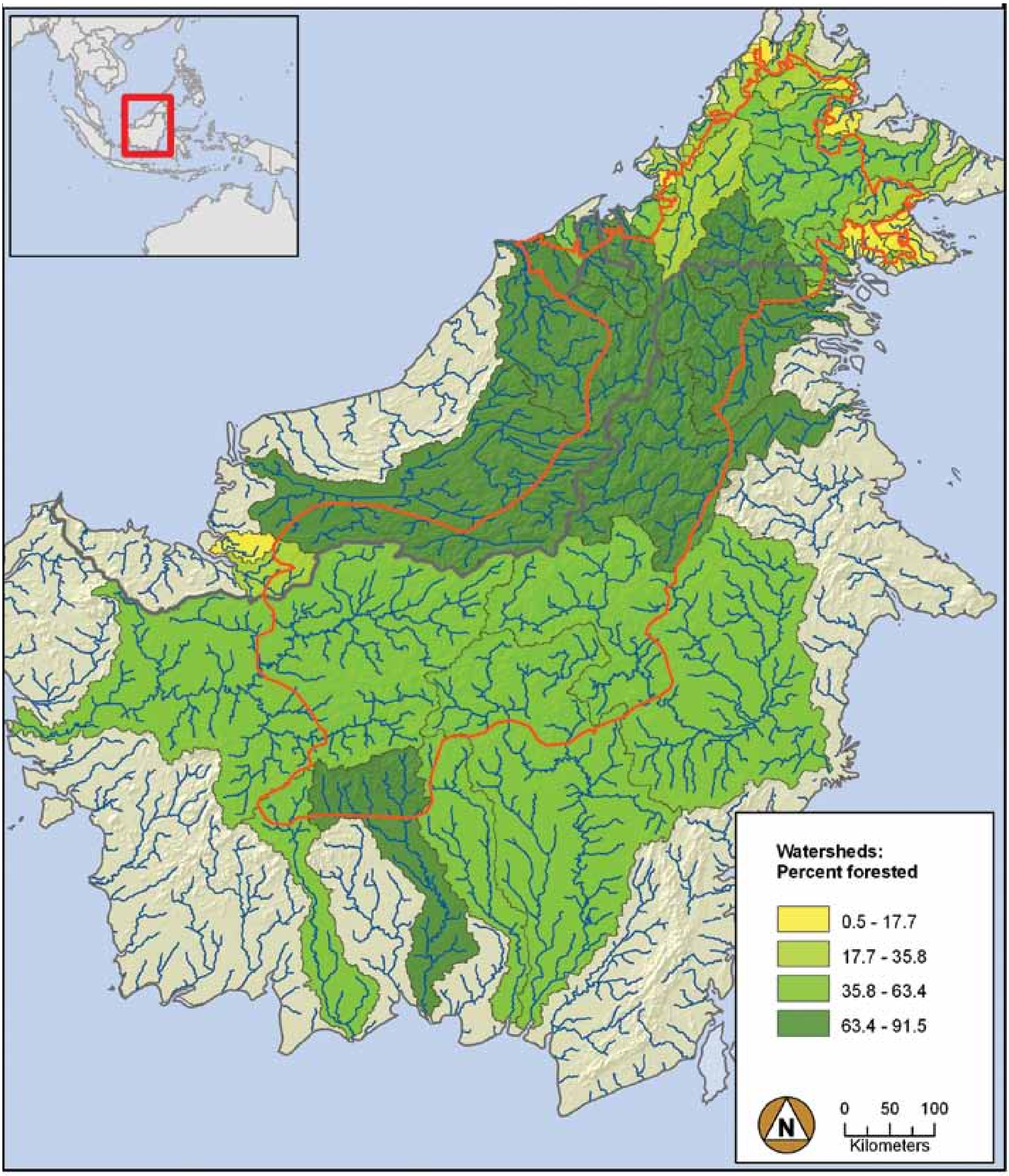
Smaller rivers such as the Segama and the Kalabakan flow mainly through areas of logging concessions. The Kinabatangan river and its many tributaries dominate most of Sabah east of the Crocker and Kinabalu range. Decent forest areas in the upper reaches are followed by plantation areas further downstream.

The drainage area of the Padas river has a relatively low forest cover, due to wood plantations and agriculture.

Most of the uplands in and around Brunei are retained as some form of forest reserve, and the watersheds of this area, including the Trusan, Temburong, Limbang and Belait, are all under good forest cover.

The Baram river rises from the slopes of Mt Murud and the Tama Abu mountain range. Both upstream and downstream sections of the Baram watershed have been extensively logged, but many areas are maintained under forest cover.

The drainage area of the Rajang river comprises much of the southern and central part of Sarawak. The uppermost reaches are at the border with the Apo Kayan in East Kalimantan. The Baleh river is a large branch of the Rajang and rises from the slopes of Mt Cemaru and other mountains in the north of West Kalimantan. Most of the Rajang watershed comprises hilly and mountainous landscapes. Logging companies have been active here for decades but have kept most of the land under forest cover. The upstream section of Lanjak Entimau is protected.


Watersheds:
Percent forested
0.5 - 17.7
17.7 - 35.8
35.8 - 63.4
63.4 - 91.5
N
0
50
100
Kilometers

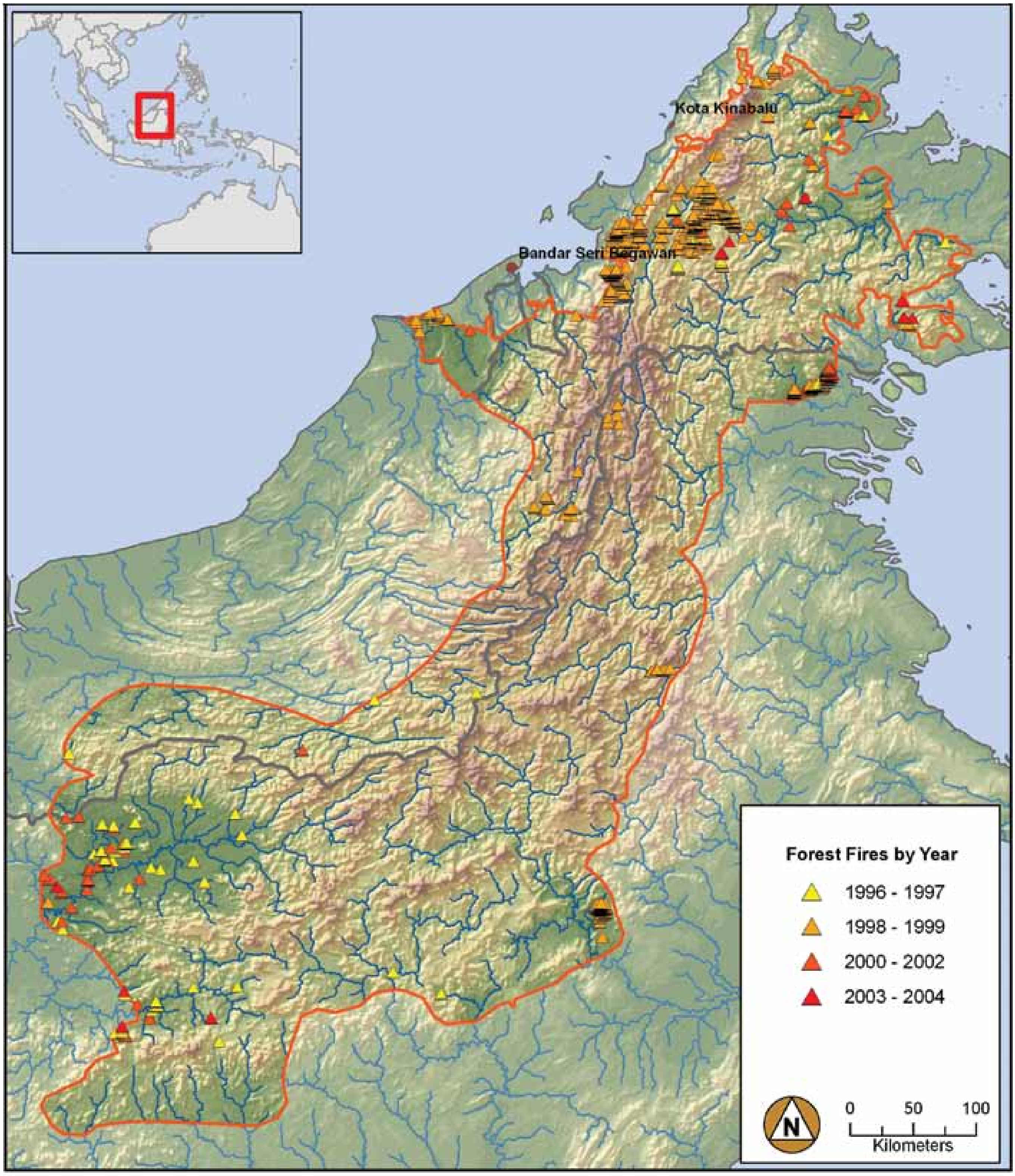
FOREST FIRE

Fires by year

By far the largest majority of forest fires occurred in 1915-16, 1982-83 and 1997-98, during the infamous extreme dry El Nino years, when small fires initiated to clear land for agriculture could spread out over large areas. However, after these events forest fires continued to occur, albeit more concentrated at the edges of the Heart of Borneo.

Most of these fires occurred in areas with high levels of forest conversion afterward, particularly in West Kalimantan and Sabah.

Lowland forest in East Kalimantan that was completely burned six years earlier. Photo: Stephan Wulffraat


Kota Kinabalu
Bandar Seri Begawan
Forest Fires by Year
1996 - 1997
1998 - 1999
2000 - 2002
2003 - 2004
N
0
50
100
Kilometers

PUTTING THE HEART OF BORNEO ON THE MAP

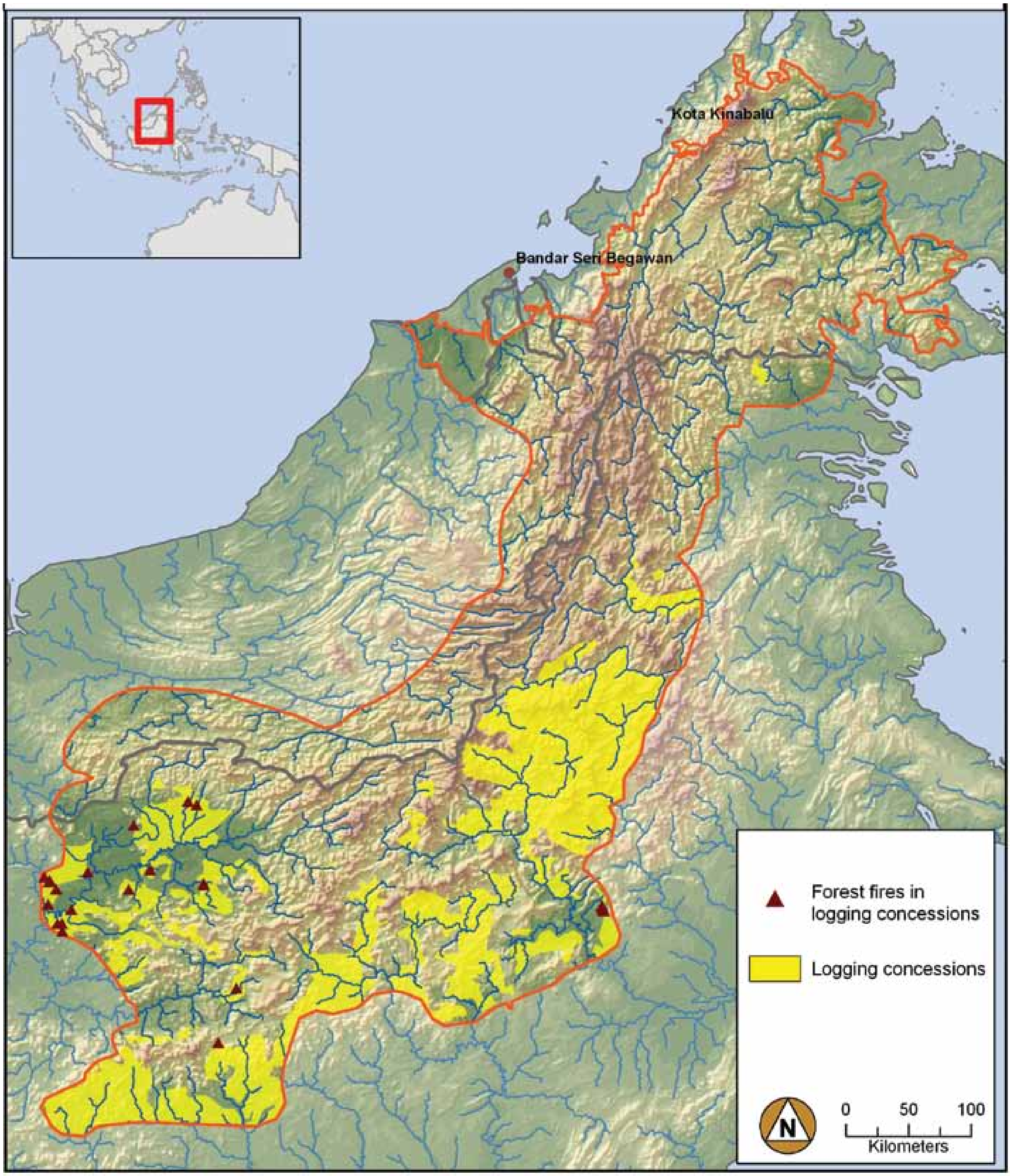
FOREST FIRE

Fires in logging concessions

Carefully managed logging concessions are not very vulnerable to forest fires. Burning is not a clearing "tool" normally used here. The remaining vegetation after logging would be dense enough to avoid dry open spots. Even if a large portion of the trees that dominate the canopy is removed, there is still a form of sub-canopy that creates a micro-climate that is more humid than an open area. The locations in a logging concession that are most prone to fire risks are the log ponds, where much dry material such as bark is left, and the sides of the wider logging roads. Still, it is unlikely that large fires would occur here.

Fires can be very convenient to developers. In Indonesia, heavily burned forest is classified as degraded and can be converted more easily into plantations. Most of the forest fires in logging concessions in the Heart of Borneo occurred in locations that border plantation development areas.

Burning forest in East Kalimantan. Photo: Stephan Wulffraat


Kota Kinabalu
Bandar Seri Begawan
Forest fires in logging concessions
Logging concessions
N
0
50
100
Kilometers

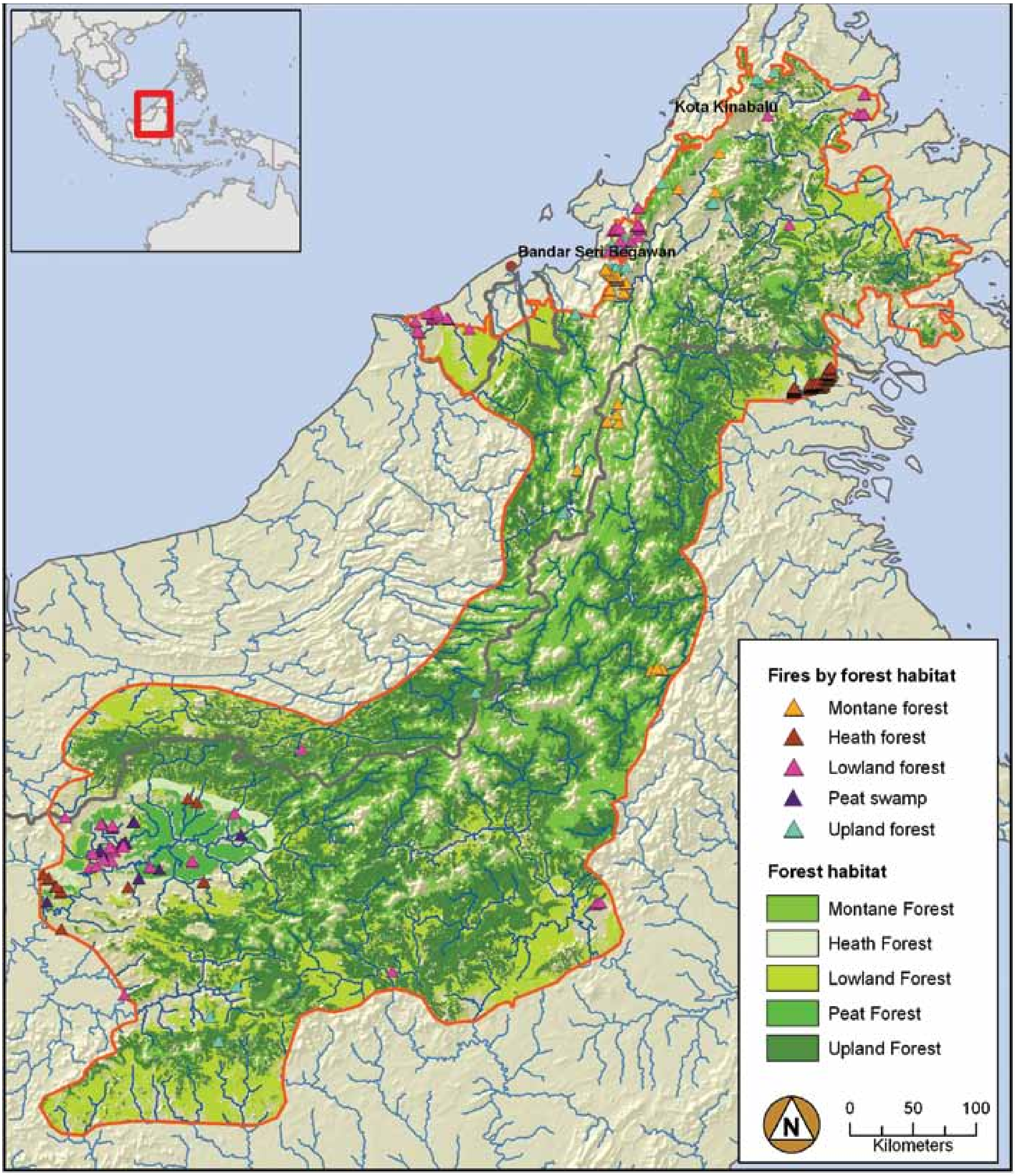
FOREST FIRE

Fires by forest habitat

The map opposite summarises the results of the ecosystem analyses on the following pages.

The most widespread forest fires occurred in lowland habitats.

Cleared forest for ladang burning. Kutai National Park, East Kalimantan. Photo: © Alain Compost / WWF-Canon


Kota Kinabalu
Bandar Seri Begawan
Fires by forest habitat
Montane forest
Heath forest
Lowland forest
Peat swamp
Upland forest
Forest habitat
Montane Forest
Heath Forest
Lowland Forest
Peat Forest
Upland Forest
N
0 50 100
Kilometers

RISK OF BURNING

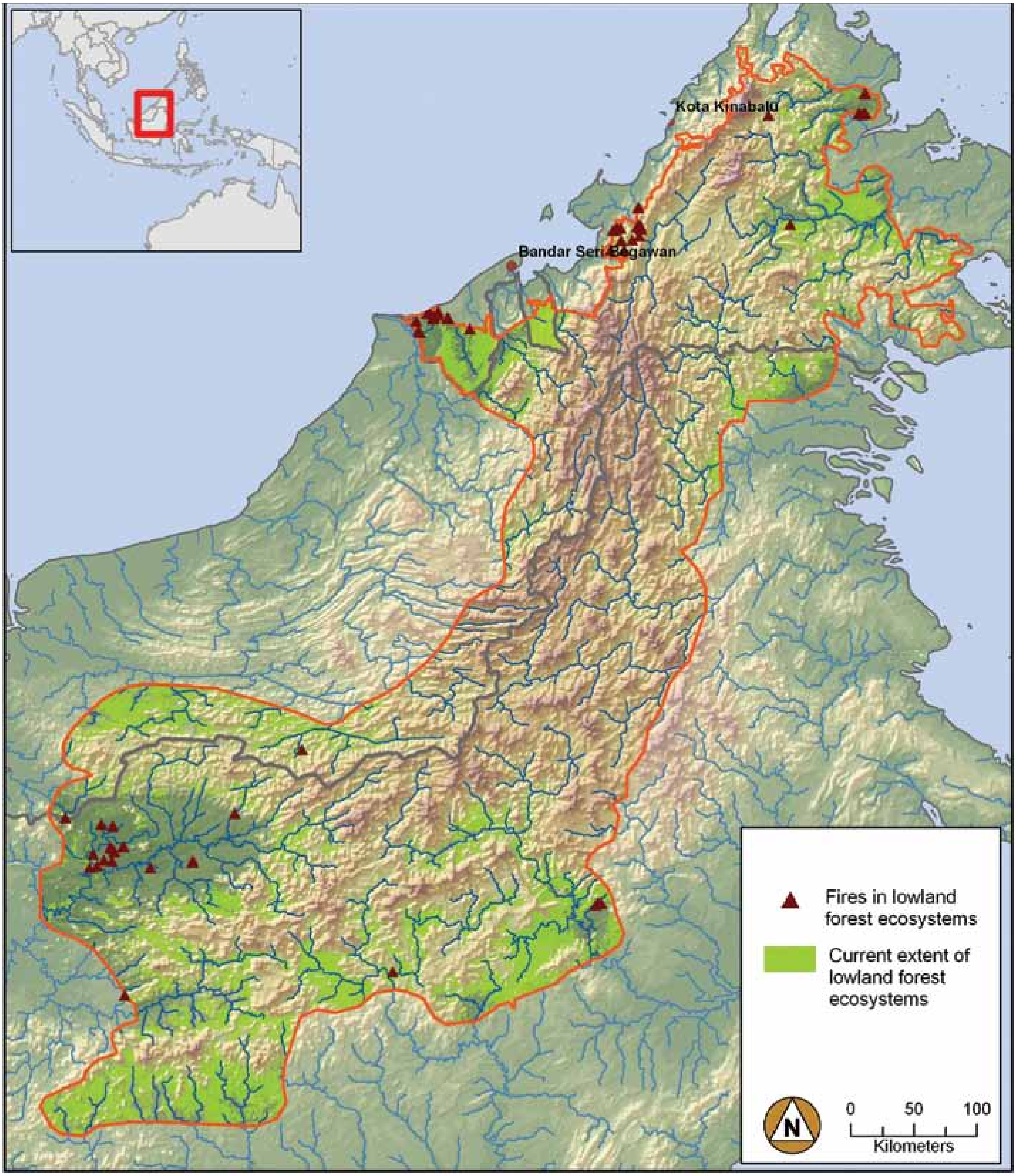
Lowland rainforest ecosystems

Lowland rainforest ecosystems are not the most common ecosystem in the HoB, but are represented by some excellent forests, some in primary conditions.

Forest fires are a major threat. Most lowlands forests were burned at the edges of the HoB and subsequently converted. This is particularly the case in West Kalimantan and the northern HoB edges of Sarawak and Sabah. These forests are lost now but fortunately some areas, not affected by forest fires, still remain further into the interior.

The lowland rainforest fires of the upper Barito area in Central Kalimantan occurred during 1997-98 and have not been repeated since.

Photo: Fighting fire in a peat moss area, Kuala Kapuas, Central Kalimantan.
© Tantyo Bangun / WWF-Canon



Kota Kinabalu
Bandar Seri Begawan
Fires in lowland forest ecosystems
Current extent of lowland forest ecosystems
N
0
50
100
Kilometers

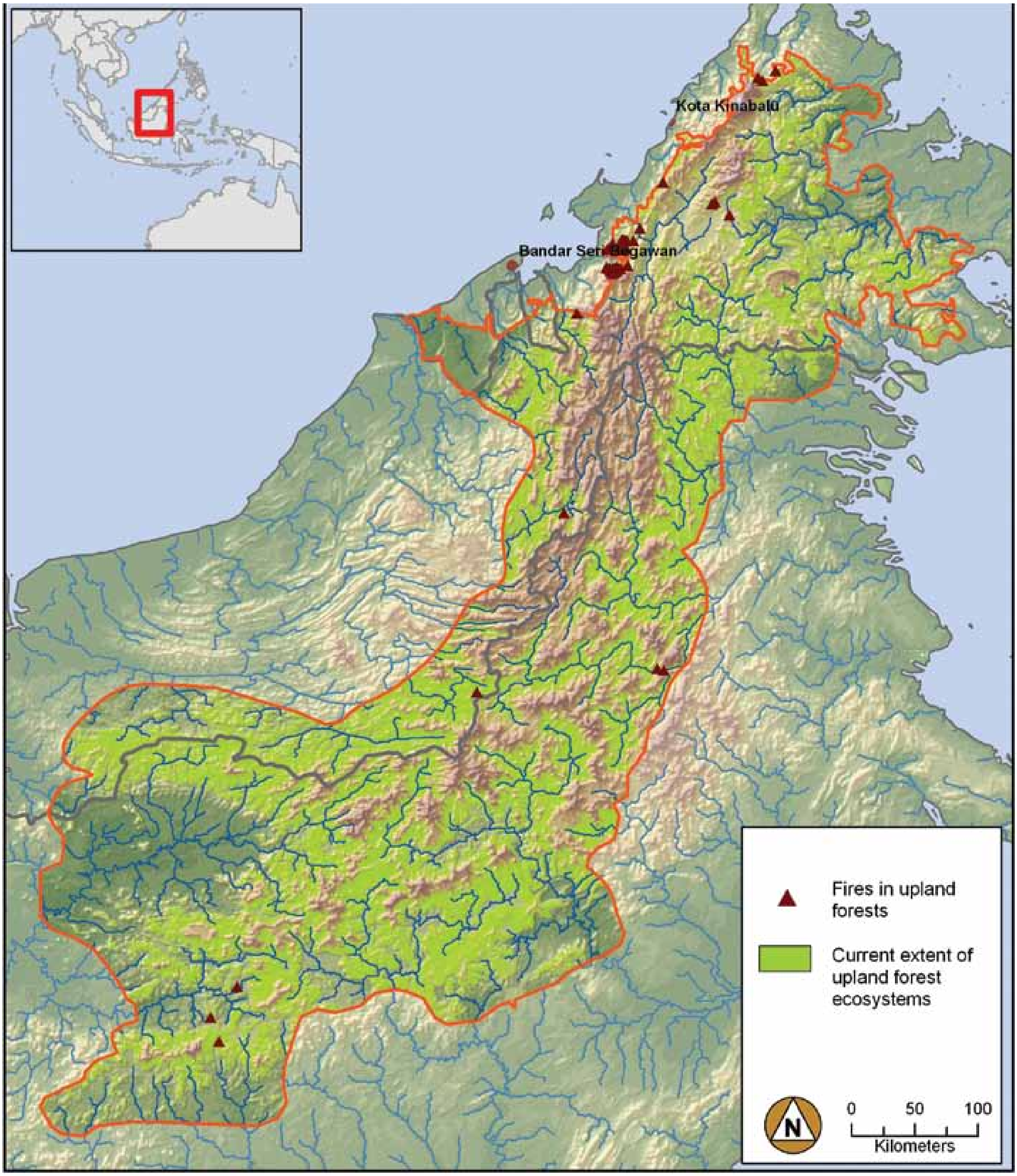
RISK OF BURNING

Upland rainforest ecosystems

Upland rainforest, the HoB's largest ecosystem, has been relatively safe from forest fires. The exception is the area in western Sabah where upland rainforests were converted. In May 1998, primary upland forest in Sabah suffered a light burn towards the end of the El Nino drought (nine months with very little rain).

The other burned locations were mainly concentrations of forest that was burned for shifting cultivation. This usually only shows up as hotspots in cases where many fields close to each other are prepared and some of the surrounding forests left standing were accidentally burned as well. These shifting cultivation fields are abandoned after one or at most two years allowing secondary forest to regrow.

Emergent Shorea trees in upland forest, East Kalimantan. Photo: Stephan Wulffraat



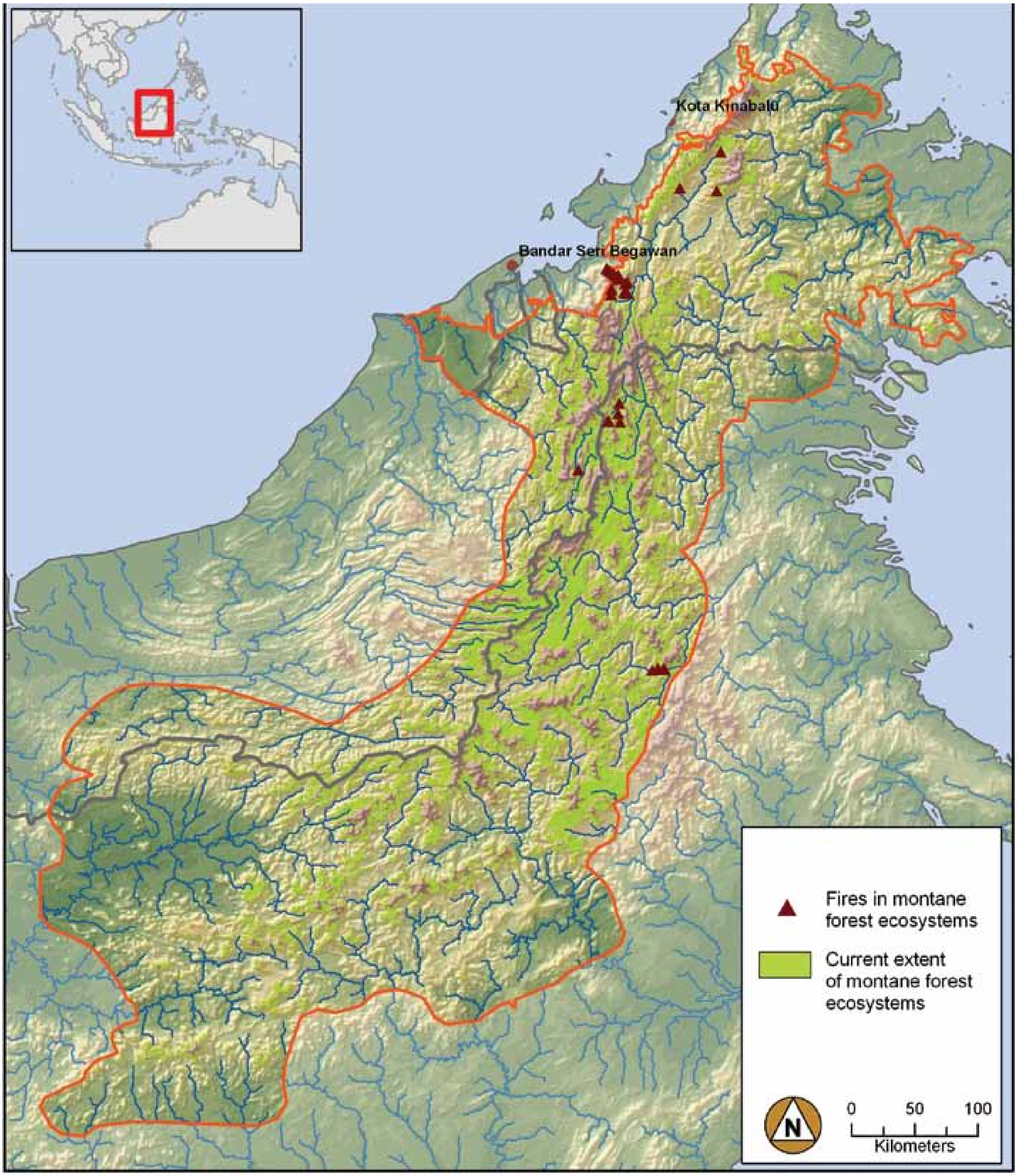
Kota Kinabalu
Bandar Seri Begawan
Fires in upland forests
Current extent of upland forest ecosystems
N
0
50
100
Kilometers

RISK OF BURNING

Montane forest ecosystems

The forest fires in montane forests of the HoB occurred mainly by accident. In the Krayan area and along the Kayan river, both in East Kalimantan, these accidental fires occurred during the extreme drought of 1998. Large parts of these forests have recovered.

Mosses at the forest floor of a montane forest in east Kalimantan. Photo: Stephan Wulffraat


Kota Kinabalu
Bandar Seri Begawan
Fires in montane forest ecosystems
Current extent of montane forest ecosystems
N
0 50 100
Kilometers

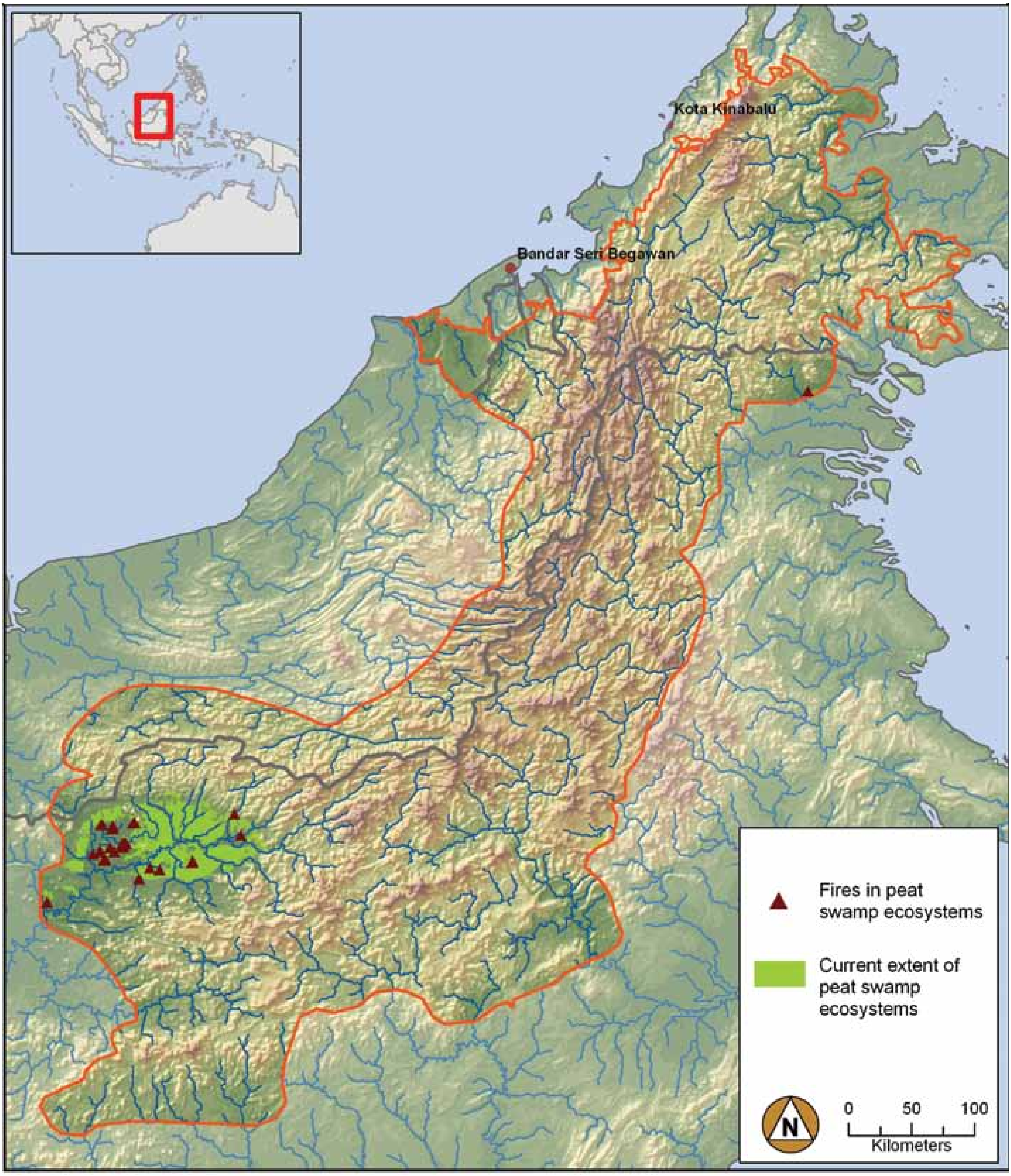
RISK OF BURNING

Peat swamp forest ecosystems

The map opposite shows that peat swamps are very susceptible to burning. The only large areas of peat swamp forests within the Heart of Borneo are in the vicinity of the Sentarum lakes. Here many locations were burned, particularly in the western area (i.e. in the National Park), which is also very fragmented. The eastern area (mainly outside the National Park) is in better condition and here opportunities for recovery and restoration are better.

The Great Fires of 1997-98 destroyed forest locations throughout the area, while the fires of more recent years mainly affected the western region.

Fire burning in a peat swamp in Central Kalimantan. Photo: Stephan Wulffraat © WWF-Indonesia/Samsul Komar


Kota Kinabalu
Bandar Seri Begawan
Fires in peat swamp ecosystems
Current extent of peat swamp ecosystems
N
0 50 100
Kilometers

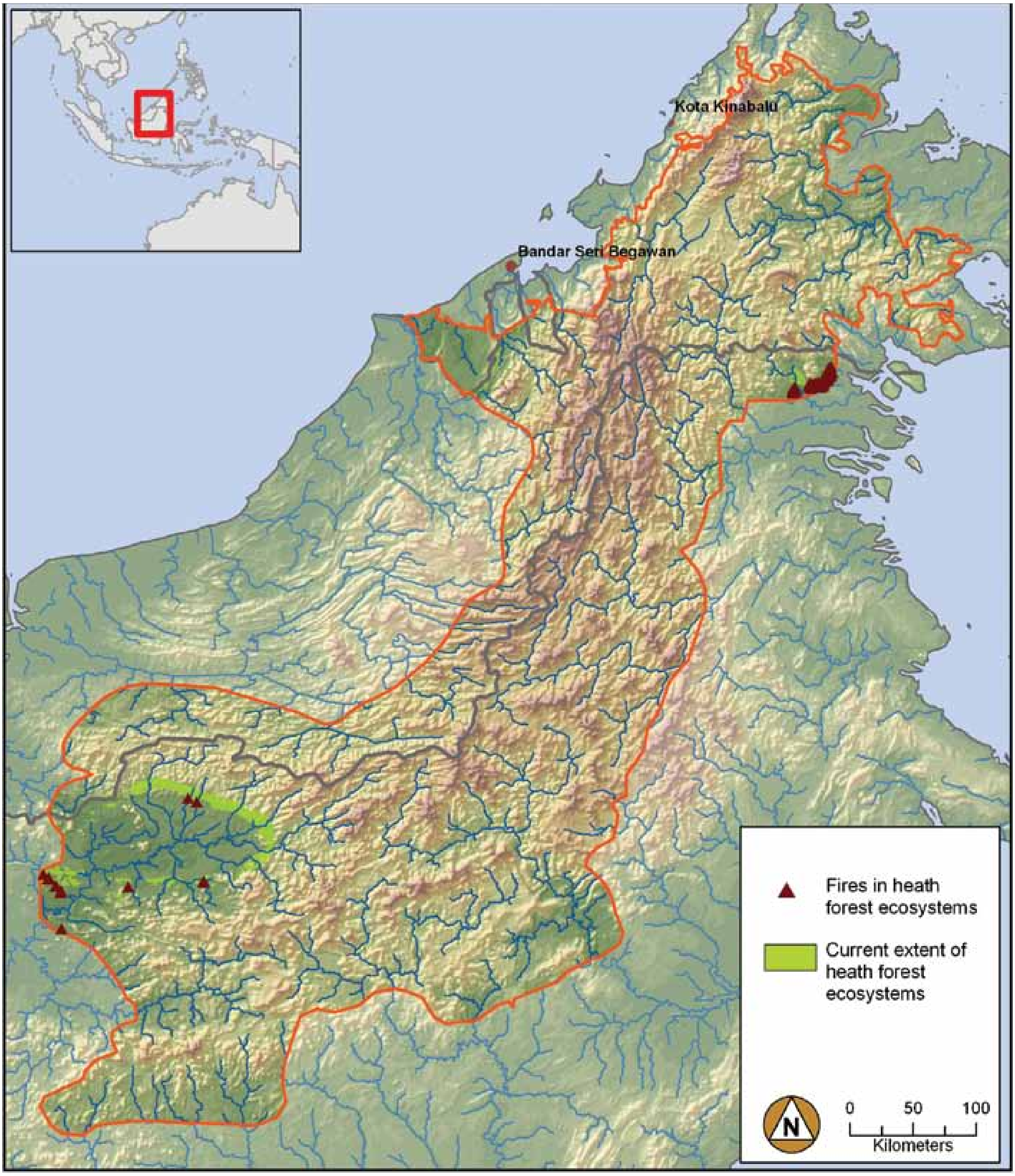
RISK OF BURNING

Heath forest ecosystems

Heath forests are generally more sensitive to burning than Dipterocarp forests, because many tree and shrub species have somewhat drier leathery leaves and there is usually thick layer of dead organic material on the forest floor. The sandy soils are very poor and most of the nutrients are in the vegetation. It takes a very long time for a heath forest to recover from burning.

The heath forests around the Sentarum area in West Kalimantan suffered the same fate as the peat swamp forests here. Again it is mainly the western part that was burned locally even in recent years. The heath forests of the Nunukan district in East Kalimantan have been strongly affected by forest fires and hardly any heath forest is left in decent conditions here.

Burned heath forest in East Kalimantan. The forest never fully recovered but remains a kind of shrub land. The only good thing is that this vegetation is usually very rich in pitcher plant and ground dwelling orchid species. Photo: Stephan Wulffraat



Kota Kinabalu
Bandar Seri Begawan
Fires in heath forest ecosystems
Current extent of heath forest ecosystems
N
0
50
100
Kilometers

Forests within plantations and concessions

A large part of the forests of the Heart of Borneo are under logging concessions. This is more than 3.7 million hectares, more than 17% of the total area of the HoB, excluding Sarawak. The logging concession areas include most of the lowlands and much of the uplands in the southern and eastern parts of the HoB. The forest concessions in Sarawak could not be displayed on the map since data are not available.

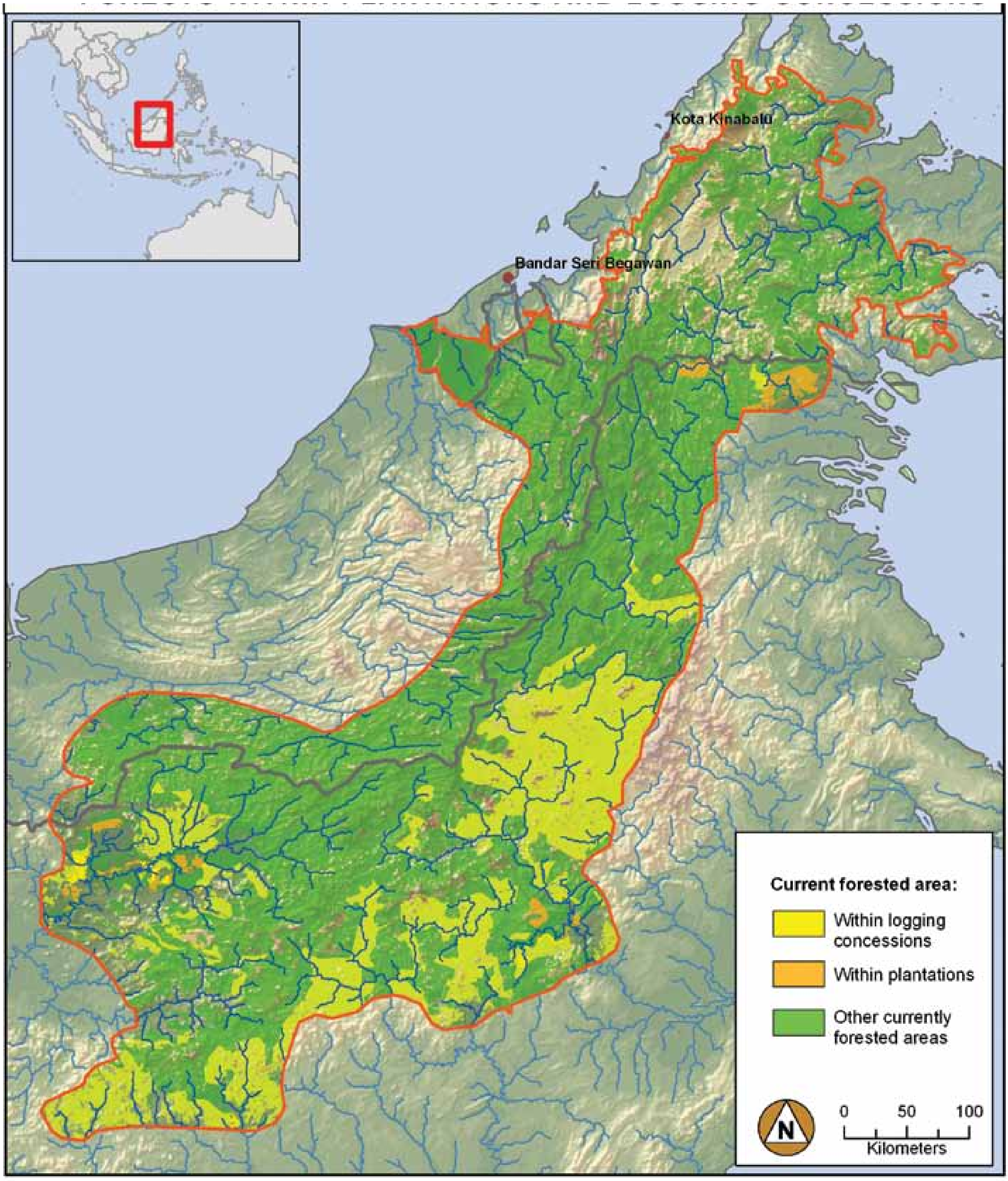
Timber production is frequently the best option to keep an area under forest cover. If a logging concession is managed in a sustainable way, many of the original conservation values can be retained. Even sensitive species such as orang-utans can survive in logging concessions, if there is a carefully implemented management plan for the populations of these species. Normally, only one location in a concession is allocated annually for logging, leaving the rest largely undisturbed for the time being.

A long-term logging concession will endeavour to leave behind a healthy forest stand after a first round of logging. The remaining trees can grow to attractive sizes and some of these can be harvested after a number of years or decades, during a second round of logging.

Forests converted to plantations lose many of their conservation values. Oil palm companies committed to sustainable development will retain a number of high conservation values areas. These areas usually include strips of riparian forests, peat swamps and critical terrains such as very steep slopes and locations with very shallow soils.

Connectivity to bordering natural areas will be important to retain conservation value of these locations for the HoB.

A logging pond in forest near Samarinda in East Kalimantan.
Photo: © Edward Parker


Kota Kinabalu
Bandar Seri Begawan
Current forested area:
Within logging concessions
Within plantations
Other currently forested areas
N
0
50
100
Kilometers

Logging

Indonesia and logging hit the headlines in a positive way in May 2010, with the announcement of President Yudhoyono's commitment to a two-year moratorium on forest and peatland clearance.

The moratorium will not affect existing concessions (nor presumably the substantial illegal logging industry).

Officially, Indonesia divides its forests into three categories: conservation, protection and production. To legally conduct logging, an entity has to apply to the government for a concession of production forest.

There are two main types of concession – natural forest and plantation forest. (The third type, restoration concession, refers to a former production concession which is no longer 'productive' but could naturally regenerate. These are used mainly for biodiversity and carbon trade).

Natural forest permits allow selective cutting of trees of species specified in the permit over 50 cm in diameter. Logging may be further limited by factors such as accessibility; for example, if the only way out is by river, loggers will only cut varieties that float.

The concessions are normally granted on a 75-year basis, with logging conducted on a 35-year rotation system. This means the concession is divided into 35 lots and each lot can only be logged one year in 35. In practice, however, many companies do not follow the system, leading to illegal levels of degradation.

Natural forest concessions have decreased from around 500 in the 1990s to around 130 in 2010, with a commensurate decrease in area. The permits have been revoked by the Ministry of Forestry, normally due to inactivity. The areas often become targets for illegal logging, or the land is given over to some other activity such as agriculture or mining.

Ironically, plantation forest concessions were introduced by the government in the 1980s in an effort to preserve natural forest. The idea was that already denuded forest areas would be planted, and would supply the raw material needed by the timber industry.

In practice, plantation forests have proven a destructive force, with many permit-holders clearing existing forests (and selling off the timber) to create the plantations.

There is some evidence that market side advocacy could lead to loggers cleaning up their act. What is clear is that the amount of certified forest in Borneo is being outpaced by forest loss.

President Yudhoyono's moratorium on forest clearance is a good start, but without a combination of market pressure and the reform of monitoring policies, the forestry industry in Borneo is more likely to collapse than continue.

– Catherine Parsons

Abandoned and collapsed logging bridge. Murung River, Central Kalimantan. Photo: Stephan Wulffraat

Production forests

The biggest change in Borneo forests over the past few decades is that old growth or virgin forests have been logged. Legal, commercial logging (now a dying industry as there are few big trees left outside protected areas) supplied mainly foreign markets with large logs, sawn timber and plywood. Chainsaws were used to cut down the trees and bulldozers to build roads and haul the logs.

Illegal logging was and is done with chainsaws. The tree trunks are cut into planks and beams in the forest, and hauled by manpower and small machines to rivers and roads, to supply local and regional markets.

The big trees cut 'legally' were 100-300 years old, while the smaller trees cut subsequently, and mainly 'illegally', were less than 100 years old.

After all the logging, the forest is badly but not irreparably damaged. Trees will grow and the forest will recover unaided if damage is moderate, or with treatment to cut weeds and plant tree seedlings if damage is great. It is important that substantial primary species are left for seeding.

Damaged natural forest is greatly superior to any kind of plantation in terms of its potential to sustain biological diversity and to prevent species extinctions.

In contrast, the role of plantations in sustaining wild species is becoming over-rated, mainly in the form of 'green-wash' lists of a very small number of robust plant and animal species that can be seen in plantations, but only as long as some natural forest remains nearby as refuges and food sources.

Old growth forests now remain only as rather small areas, predominantly in remote hills and mountains. Hardly any old growth lowland rainforests remain. Logged forests, however badly damaged, represent a crucial element in sustaining Borneo's remaining natural biodiversity.

Apart from the difficult problems of encroachment by farmers and fires escaping into logged forests from plantation development, an underlying problem with sustaining logged forests in lowlands is that they have no obvious or realisable value to governments or businesses. Their timber value has gone and will not return for many decades. The land on which the logged forest exists has better economic value if converted to plantations of oil palm, rubber or monoculture fast-growing timber trees.

A policy decision by governments to retain production forests is necessary for the future of lowland rainforests in Borneo. Sabah has shown a lead. Specific, demarcated forest management units (FMUs) of 50,000 to 100,000 hectares are coming under 10-year rolling management plans, some licensed for up to 100 years to companies, some managed by government. A part of the FMU may be allocated for fast-growing tree species, while the remainder is allowed to regenerate naturally. By having a mix of native tree species in the plantations, the problems of biodiversity conservation in exotic monocultures are reduced.

The way forward may be to harvest fast-growing native 'pioneer' trees on cycles of 12-20 years, on the basis of volume removable per hectare after their initial fast growth. Without such a system, Borneo lowland plant and animal species will start to become extinct in the coming years.

– Junaidi Payne

Cutting down a tree in a logging concession. Photo: Sugeng Hendratmo

Concentrations of coal mining concessions

The map below indicates where most of the coal mining concessions are concentrated and should not be considered an official concessions map.

Many of the coal mining concessions are concentrated in Central Kalimantan province. The drainage areas of the upper Barito and Murung river are known to have rather large coal deposits, which are found not far below the surface.

The concessions are located in areas covered by lowland and lower upland rainforests, which are generally extremely rich in tree species. Moreover, the lowland rainforests of the Murung area are some of the last lowland rainforests of Borneo still in primary condition.

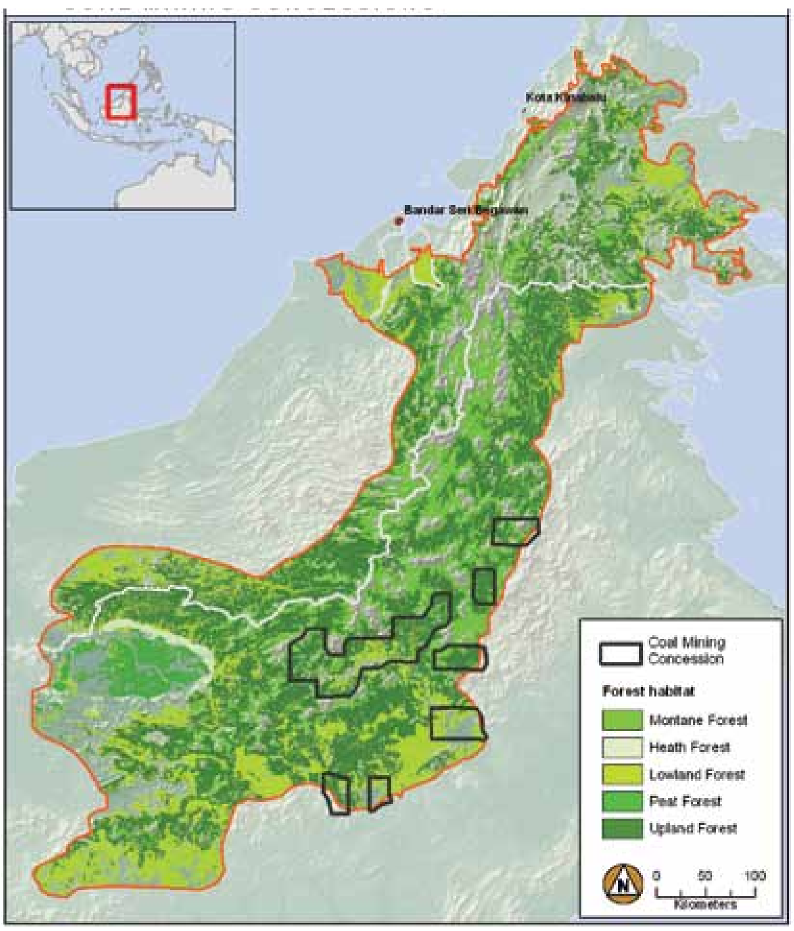
Logging concessions and mining concessions can, and frequently do, overlap. Sections of an area managed by a logging company and, thus, likely to remain under (secondary) forest cover, can still be leased to a mining company. A large mining concession holder can also sub-lease sections of the concession to smaller companies.

Large companies active in Central Kalimantan include BHP Billiton and its subsidiary Maruwai coal. There are, however, a high number of small companies with small, operational concessions often of a few thousand hectares. Information on the status and locations of these small companies is not widely available, and agreements seem to be made particularly often at local levels.

Coal mining in Kalimantan is done solely by open pit mining, with the coal layers available conveniently close below the surface. The forest vegetation and the layer of clay, sand and rocks need to be removed, after which the digging can begin. Coal mining is, by default, very destructive to the natural environment. Furthermore, large quantities of waste are produced and rivers can easily become contaminated.

Responsible companies can, however, do much work to reduce the environmental impacts. Waste heaps as well as water runoff can be managed. It is even possible to more or less restore an area after mining has finished taking out the coal. In this case, the original soil layers are redeposited back in the mining pits, at least in locations that were not dug too deep. Trees can be replanted in these soil layers, while natural regeneration will also do its job. The deepest locations will form small lakes which might become habitats for some interesting animal species.

Unfortunately, the small mining companies are difficult to control and are generally not inclined to fix up the mess they leave behind.



Mining

Indonesia is the world's third largest exporter of steaming coal, and more than half its stock is in East and South Kalimantan in Borneo. Gold is also heavily mined in the region.

Borneo relies heavily on government regulation and oversight to protect it from the environmental devastation that can accompany strip mining or the toxic by-products of gold mining, including forest degradation, flooding, contaminated water and cross-effects (e.g. new access roads built for the mines can lead to illegal logging in other areas).

In January 2009, Indonesian President Yudhoyono ratified a new Mining Law that will radically overhaul the mining landscape in Indonesia. The law is slowly being shaped by various further regulations that clarify or provide detail. Under the new law, mining can be conducted only in areas that the Central Government designates as 'open' for mining. In theory, this will reduce the potential for overlap in concessions by other industries, such as forestry or agriculture. In practice, this will be contingent on the quick completion of spatial planning processes to allocate areas 'open' to mining or otherwise.

Separately, a new Ministry of Forestry regulation (issued in 2010) will allow underground mining in protection forests. It is as yet unclear how this will link with the granting of mining concessions. Companies can apply for either an exploration or production licence. These could be granted at Ministerial, Governorial or Mayoral level, depending on whether the area affected (including environmentally) crosses provincial or regency boundaries.

The law also provides for differing concession areas depending on the mineral involved.

Coal will see exploration permits from 5,000 to 50,000 ha, which must reduce to 25,000 ha after three years. A production permit will be a maximum of 15,000 ha.

Metallic minerals permits will be granted from 5,000 to 100,000 ha initially, to be reduced to 50,000 ha after three years. Production will be a maximum of 25,000 ha.

Currently, exhausted mining areas are often abandoned without any attempt at rehabilitation. Under the new law, permit holders will be required to provide guarantees for reclamation and post-mining activities,in the form of a bank guarantee or deposit, etc.

The Mining Law is the Indonesian government's attempt to manage the inevitable trade-offs between the exploitation of natural resources and its environmental impact. It is not designed to halt environmental degradation and may do little to slow it. This is a law designed for the long game; the Heart of Borneo may not have that much time.

– Catherine Parsons

Layer of coal in East Kalimantan. Photo: Stephan Wulffraat

Establishing a new oil palm plantation

This case study, from East Kalimantan, is an example of appropriate planning and development of a new oil palm plantation in which environmental factors are taken into account.

The acquired land was a former logging concession, abandoned about 10 years ago. The logging company had taken out most of the larger trees and the entire area is criss-crossed by logging trails. Parts of the area were severely burned afterwards and nearly all the surviving trees were taken by local communities.

The remaining vegetation was mainly young secondary forest, with patches of the original forest left inside. Only the steepest slopes and small river valleys were spared.

The land preparation for developing the oil palm plantation starts with an inventory of terrain types, soils, hydrology and drainage patterns. This area has hills and undulating areas with sandy-loamy and rather infertile soils in the northern part and flat terrain with fertile clay soils in the southern part. The area is dissected by a rather wide river valley and narrow valleys along its tributaries.

The optimum locations for the main roads are established and an assessment for the need for bridges and drainage channels is made. In this case, the old main logging road could be used, with new auxiliary roads built to enter the central area. Drainage channels were only needed in the southern part. A block layout is then mapped and designed, dividing the entire area into numbered blocks that are surrounded by trails, which will enable the future transportation of the oil palm fruits.

A High Conservation Value areas assessment starts with identification of potential areas from satellite images but, given the scale, most locations need to be checked directly in the field. A convenient way to identify High Conservation Value areas is by applying the HCV toolkit. Additional vegetation and wildlife inventories of promising areas strengthen the argument to preserve HCV areas as designated 'conservation areas'. Some plantations prefer to use 'green belts', which are not exactly the same.

An assessment of endangered species includes more than larger mammal and bird species. For instance, many of the amphibian and reptile species of Borneo are endemic. The issue of critical temporal use applies in this case mainly to migratory birds that use the riversides each year. A number of tree species are also on the IUCN Red List.

Undisturbed lowland rainforest is becoming an endangered ecosystem and even small areas of this extremely species-rich forest are worth preserving. Small patches of heath forest and peat swamp forest, even disturbed, should also be set aside.

Riparian forests and remaining forests on steep slopes are of major importance to water catchment and erosion control. The forests of the central river valleys also serve as a barrier against potential fires spreading over the area. Fish is an important source of protein for local communities. These communities rely strongly on the

Opening land with bulldozers for establishing a new oil palm plantation. Photo: Stephan Wulffraat remaining forests for harvesting essential products such as rattan and wood, which are used for everyday tools.

After finishing the HCV assessment process, the conservation areas are mapped and the boundaries are tagged in the field.

Only then can the terrain preparation start. The areas designated for plantation are cleared from vegetation. Large trees are cut down first but endangered species such as Koompassia are left standing. Then shovels and bulldozers remove the entire terrain of all other vegetation, leaving the soil bare. The dead vegetation is piled in rows and left to decay. The plantation company does not apply any burning.

The terrain preparation continues with flattening the land by bulldozers and digging additional drainage channels using excavators. A basic road system is built around the designated blocks.

Planting stock has been raised at a previously established nursery. The young oil palm trees are typically between 1-2 m high when planted. The open terrain around the young palms is sown in for a temporary ground cover of legume creepers. This will avert the growth of weeds and, at the same time, function as a green fertiliser.

New oil palm plantation with conservation area set aside along a stream, East Kalimantan. Photo: Stephan Wulffraat

Afterwards artificial fertilisers are applied. The first harvest of the oil palm fruits can usually take place after three years.

– Stephan Wulffraat

Illegal logging

Illegal logging usually refers to extracting timber at a commercial scale from forest areas where this is not allowed. The most evident cases are in protected areas such as National Parks but it also occurs in Protection Forests, which have a less defined conservation status. Many abandoned and mainly logged-over timber concessions are subject to illegal logging. Areas that are designated for oil palm plantations often attract loggers who try to take out as much timber as possible, even from those sections that were supposed to be retained as green-belts or conservation areas. Extraction of small volumes of timber by local communities for local use is generally not classified as illegal logging, as impacts on the forest ecosystem are limited.

Illegal logging in Kalimantan is often initiated by outside entrepreneurs collaborating with local field organisers and is often linked to an extensive transport and trade network. Illegally cut logs are processed in local sawmills or exported. In 2005, 137 border points were identified where timber was being trafficked. (Several analyses by Krystof Obidzinski and his team at the Center for International Forestry Research (CIFOR) in Indonesia explained most aspects of illegal logging in Kalimantan.)

Illegal logging can have a devastating impact on a forest ecosystem. Logged-over forests are often still in reasonably good condition. Although most of the larger trees were removed, a significant number of trees are left standing, including commercial species with smaller diameters, and a canopy (albeit partly opened) still exists. Regeneration of saplings and young trees is abundant. Illegal loggers take out most of the remaining timber, thus removing all the seed-producing trees needed for regeneration of commercial species and opening the entire canopy. Forest ecosystems are set back almost to a stage of re-growth on open land.

Illegal logging can have a devastating impact on a forest ecosystem. Photo: Stephen Wulffraat

Bornean elephant distribution

The elephants of Borneo have a rather limited distribution and are found mainly in the eastern part of Sabah and the northernmost part of East Kalimantan.

It is likely that the elephant distribution in the 1960s was not much different from the historical distribution. Forest conversion and development for large-scale plantations started in this part of Borneo in the 1970s.

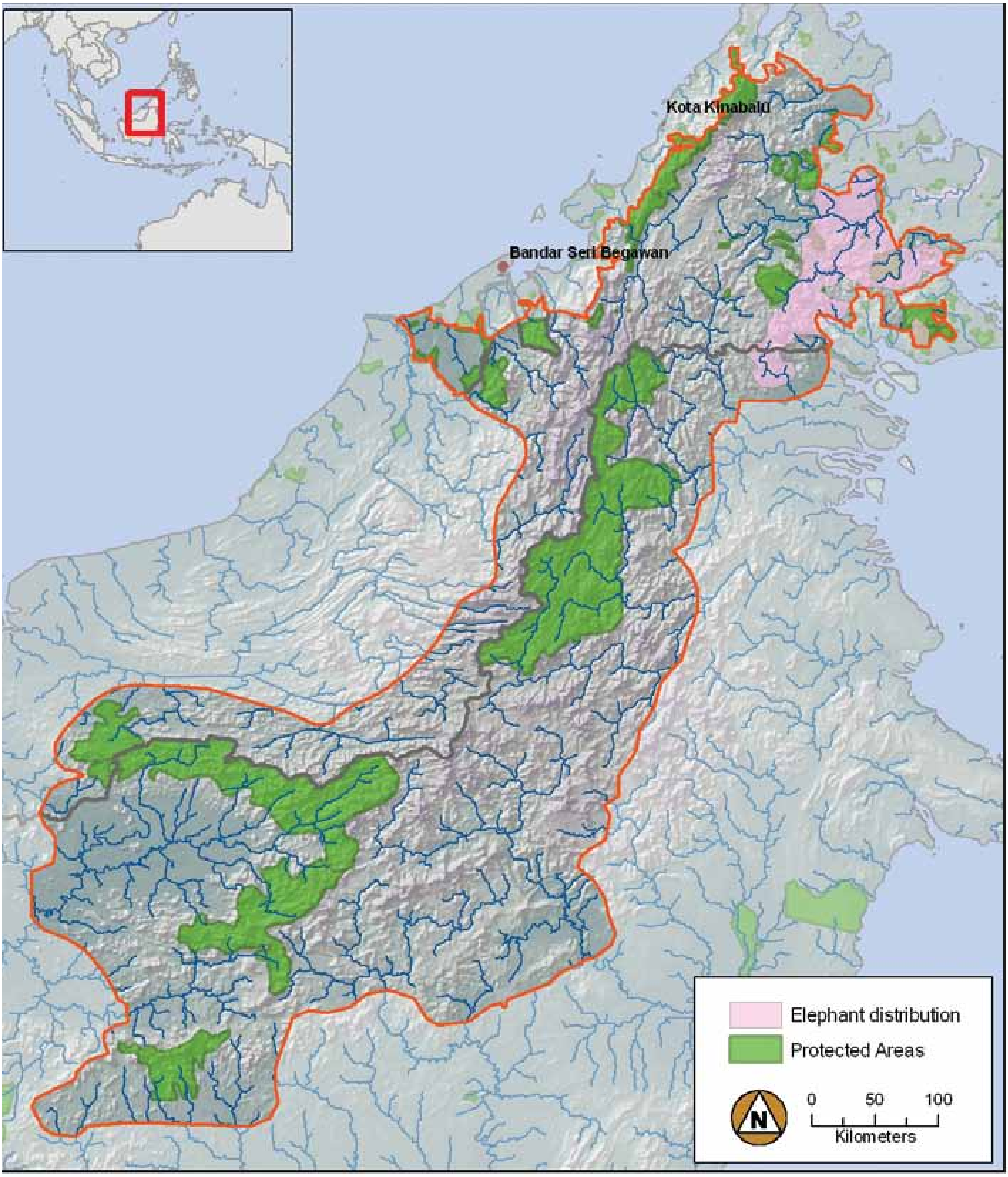
Most of the habitat conversion of the past 10-30 years took place in lowlands outside of the HoB boundaries. Conversion of elephant habitat and decrease of distribution within the HoB does not seem to be very evident. However, about two thirds of the remaining elephant populations live inside the HoB boundaries.

The major elephant habitat outside the HoB is the Tabin Wildlife Reserve and lower Kinabatangan area, where large numbers of elephants are concentrated after their orginal habitats in the surrounding areas were converted.

Most areas of current elephant habitat in Sabah have the status of permanent Forest Reserves.

The elephants of East Kalimantan are found only in the Nunukan district, and mainly in the Sebuku sub-district. Part of this habitat is under logging concessions, but an essential section which is in the migration routes of the elephants is currently being converted to oil palm and pulp wood plantations.

Elephants have a strong preference for lowland and riparian forests, including (shallow) swamps in these ecosystems. These habitats do not necessarily have to be in primary condition, and elephants often use secondary vegetation that has a higher portion of herbaceous plants on which they feed. Favourite items on their menu in Borneo are wild bananas, wild ginger species and *Arenga undulatifolia* palms. (And the hearts of young oil palms, causing many conflicts with newly established plantations.)



OPPOSITE: Herd of Bornean Pygmy elephants (Elephas maximus borneensis) crossing a road in the Danum Valley Conservation Area, Sabah, North Borneo, Malaysia. Copyright: © Cede Prudente / WWF

The elephants of Borneo: the origin mystery

The elephants of Borneo are found only in the eastern part of Sabah and the adjacent northernmost part of East Kalimantan. No signs of wild elephants have ever been found in any other part of Borneo.

While fossil molars from Pleistocene elephants are attributed to the Niah caves in Sarawak, it is not known whether these were originally from Borneo. Elephant bones excavated near Banjarmasin were most likely from an imported elephant kept at the court of the Sultan (Cranbrook, Payne & Leh, 2008).

A Dutch military commander, Lt. Col. Habbema, based in East Kalimantan in the 1930s, did an extensive survey on local elephant records by interviewing people throughout eastern Kalimantan. He checked with many Punan, Kayan, Tidung, Bulungan and Kenyah people (including the most knowledgeable Kenyah historian at Long Nawang), but did not get a single historic record, memory or even myth about the presence of elephants in their areas.

The limited elephant distribution is remarkable, particularly since there is suitable habitat all over Borneo and the human population pressure is less than in Sumatra, where elephants are found throughout.

It has been the popular belief that the elephants were introduced to the east coast of Sabah by the sultan of Sulu, some 200-300 years ago. A few animals were released and have in the course of time established the current feral population.

In 2003, the results of DNA analysis of Borneo elephants were published in which it was demonstrated that the elephants from Borneo are genetically distinct and considerably different from elephants from Sumatra, Peninsular Malaysia and other mainland populations. This led to the conclusion that the elephants are native to Borneo and not a feral population (Fernando et al, 2003).

However, the results of the DNA analysis did not entirely exclude other possibilities. It is still possible that Borneo elephants are genetically similar to another population that was not included in the comparative analysis; either because samples were not available or because the samples do not exist anymore because the population has become extinct.

In 2008, a new hypothesis was published stating that the population of elephants of north-eastern Borneo consists of descendants from introduced individuals of the now extinct Javan elephant. The elephants would then have been transported to Borneo by the sultan of Sulu, as mentioned by several sources.

A record tells of a shipment of two elephants from the raja of Java given to the ruler of Sulu around 1395. The existence of wild-living herds of elephants on the island of Sulu (southern Philippines) was reported in the 18th century. The elephant population was, however, exterminated by the 19th century because they were too destructive to local crops and no longer had a local use. (Cranbrook, Payne & Leh, 2008).

There are many written records of domesticated elephants kept at royal courts in Java up to the 18th century, and elephants were transported for trade and as gifts throughout the archipelago.

However, very little is known about the presence of wild elephants in Java, and there is sparse evidence of wild elephants during the time that the elephants were sent to Sulu.

Several archeological records of fossil elephant remains are known from Java. One individual was estimated to have died some 200,000 years ago and is actually a different, more ancient species than the modern Asian elephant *Elephas maximus* (Nurfika Osman, 2009). The only more recent specimen, from around 1350 AD, is from a site between Jakarta and Bantam (Cranbrook, Payne & Leh, 2008) and could well be from a domesticated elephant. According to another source (Joniansyah, 2004) this elephant fossil is 7,000 years old.

Perhaps the oldest depictions of elephants in Java are those on the Borobudur, assumed to have been made around 800 AD. Here we find carvings of elephants both living in the wild as well as domesticated. The accurate representation of the elephant bodies could lead to the conclusion that the elephant was native to Java at the time the carvings were made (Cammerloher, 1931).

Maclaine Campbell (1915) cites several early European natural-history records from Java.

One of the earliest records is from a traveller who visited Java in 1640: "Java abounds both in wild and tame beasts; the forests are filled with elephants, rhinoceros, leopards, tigers, serpents, lizards, hogs without bristles." It is, however, not clear whether the traveller had seen elephants for himself or relied on secondary sources. There is no Dutch colonial record of wild elephant populations from Java (Veth, 1882). Raffles (1830) frequently mentioned elephants at royal courts but not wild elephants in Java.

Further on, a record from 1823 mentions that: "The forests of Java are inhabited by the rhinoceros, tiger, black tiger, leopard, tiger cat, boa-constrictor, and a variety of animals of milder natures. The elephant is not found in its wild state in these woods, though numerous in those of the neighbouring island."

The author himself writes: "As to useful or domestic quadrupeds, it may be mentioned that neither the elephant, the rhinoceros nor the camel exists today in Java. The first-named, however, was found until about 1650. It was of the Ceylon species and very small. At the time of the empire of Majapahit a number were kept in captivity, and were trained for carrying the maharajah on state occasions. Seeing that elephants are found in Sumatra at the present day in great numbers, there is nothing extraordinary in their having once been found in Java."

If elephants were transported from Java to Sulu and then from Sulu to Borneo, the question remains whether these individuals were from native wild Javan stock. It is more likely that these animals were domesticated elephants from royal courts in Java. These elephants could have been brought in earlier from areas outside of Java, or could have been descendants of wild elephants from Java.

The fact still stands that the Borneo elephant was found to be a distinct sub-species. Whether these elephants are descendants from an extinct population, from a still existing but unique population or the remnants of a native population, their conservation priorities remain the same.

– Stephan Wulffraat

Solitary male elephant in the north of East Kalimantan. Photo: Stephan Wulffraat.

Banteng

The banteng is one of the last wild cattle species in the world. They were once present in most parts of South-East Asia but the distribution of these animals is now limited to small, scattered populations in Burma, Laos, Indochina, Thailand, Java and Borneo.

The banteng is one of the largest mammals of Borneo and is an unquestionable part of the ecosystems here. Their presence in certain areas is often 'taken for granted' but the conservation of this species in the HoB deserves more attention.

Banteng are grazers and browsers, feeding on grasses, herbs and shrubs. They strongly prefer open areas in the forest and forest edges where these plants are abundant. Dense forests with closed canopies provide relatively few foods and are used mainly for hiding and resting.

When Borneo was still almost completely covered with dense forests, banteng would probably have lived mainly around gaps and other partly open areas, such as former landslides and flood plains along rivers. Once people started to clear the forest for cultivation, the banteng would have benefitted from the expansion of open areas and their numbers would have increased.

Many of the locations where banteng are known to be historically present are areas of former cultivation that form a landscape of grasslands, bushes and forest patches.

Hunting pressure would have been an issue in areas like these, but with an abundance of food available the banteng population could still have been stable or even increase.

Some domestication of wild banteng might have occurred and banteng might have interbred with domestic cattle. The major cattle of Kalimantan, the so-called Bali cattle, look very much like bantengs. Domestic bulls are, however, (dark) brown, while the banteng bull is black.

One of the largest populations of banteng in Borneo lives in and around the grasslands of the upper Bahau of Kayan Mentarang National Park. This is an area of former cultivation that is still kept open by frequent burning by local communities. Kayan Mentarang, where a small number of banteng was observed, is also an abandoned cultivation area that has become an open forest with many small grasslands and shrubs.

Numerous historical records of banteng exist for East Kalimantan and also for the northern part of Central Kalimantan.

The presence of banteng herds is relatively well documented for Sabah, including the Kinabatangan area and Tabin. There are no recent records from Brunei and Sarawak (Payne, Francis & Phillipps, 1985).

A reliable distribution map for banteng in Borneo does not yet exist because distribution records are still very incomplete.

– Stephan Wulffraat

Banteng herd in the grasslands of the upper Bahau, Kayan Mentarang National Park. Photo: Kule Anyie

Bearded pigs

Bearded pigs (*Sus barbatus*) are found only in peninsular Malayia, Sumatra, the Philippines and Borneo. The limited distribution might reflect a strong evolutionary specialisation to wet tropical habitats in the western part of Sundaland. The species might also be unable to compete with the much more widespread wild boar (*Sus scrofa*) in areas with different climates.

Bearded pigs are living in most areas of Borneo, from the lowlands, including swamp forests, to high elevations. The lowlands are the most productive habitats, but some of their most often available food (Fagaceae fruits) grows at higher elevations.

Bearded pigs prefer forest habitats but can survive well in degraded forests and shrub lands. They will visit open grasslands to forage and come into cultivated areas, where they can be a nuisance to farmers. They will inhabit wide agricultural areas such as oil palm and rubber plantations, as long as there are sufficient green belts or forested areas in the vicinity.

Bearded pig populations are very high in logged forest areas in eastern Sabah. In some locations their numbers are high enough to damage prospects for forest regeneration (J. Payne, pers. comm.).

The presence of bearded pigs in an area is usually quite clear. The animals often forage along streams and dig for roots and worms. Wallows are created and maintained for many generations. A female pig prepares a nest out of fresh leaves on the ground for giving birth.

Diet studies at Lalut Birai in East Kalimantan revealed several interesting facts: as expected, forest nuts (Fagaceae, Dipterocarpaceae, Meliaceae and others) make up a large part of the pigs' diet but a wide variety of other food is taken, including beetles and worms. They scavenge on carcasses of many different animals. The fruits of *Arenga undulatifolia* were found to play an important bridging role during periods when forest nuts are scarce.

The female pigs become fertile when they are less than two years old and usually give birth to 2-3, although sometimes up to 8, piglets. The gestation period is about 4 months. They usually give birth once a year, or occasionally twice. The interval between births and the number of piglets per birth is probably related to food availability. The pigs' adaptive behaviour and potential for producing offspring without many restrictions make the bearded pig a resilient species.

The major pig predators in Borneo are clouded leopard and pythons, but most of all, man. Pigs are the favourite food of most people living in the interior of Borneo.

Bearded pig distribution is subject to seasonal fluctuation. Indications from East Kalimantan are that during dry periods the pigs retreat to higher elevations where nuts are available most times of the year, albeit in lower quantities per hectare than in the lowlands.

An aspect of bearded pigs in Borneo that has been given much attention are the so-called mass migrations. Movements of large numbers of pigs usually occur during mast fruiting periods of Dipterocarpaceae, which occurs every 4-6 years. Apparently, major well-established migration routes exist in Borneo, but this could simply be explained as mass movements from the upland to lowland areas where the majority of Dipterocarpaceae trees are fruiting, which is mainly determined by geomorphology. Large numbers of bearded pigs cross the interior rivers at locations that are most suitable for them. Local hunters often know these locations from experience and await the animals for an easy harvest of pork.

The importance of bearded pigs for conservation cannot be underestimated. Wild pork is by far the favourite source of protein for most of the indigenous communities of the HoB. People going on a hunting trip will always first look for pigs. Traditional hunters use spears and hunting dogs that are trained specifically to search for pigs. Deer is usually their second choice. However, hunters do not want to come home empty-handed, so if they cannot find any pig or deer, they will try to get whatever animal they can on their return trip. This would also include primates, which they usually do not favour as a meal.

Their resilience, behaviour and abundance make the bearded pig one of the most important mammal species of Borneo.

– Stephan Wulffraat

Sumatran rhinoceros: present habitat

The Asian two-horned rhinoceros was formerly distributed through a large part of western South-East Asia, but nowadays only a few populations are left in peninsular Malaysia, Sumatra and Borneo. All confirmed sightings in Borneo are in Sabah.

The Asian two-horned rhino (*Dicerorhinus sumatrensis*), also called Sumatran rhinoceros, is the smallest rhino species in the world. The horns are generally smaller than on any of the other species and the second horn is often hardly developed. Nevertheless, this species has been severely hunted for its horns, for use in traditional Chinese medicines.

This species can live in a broad range of habitats, from swamp areas to lower montane forests, but its population density in Borneo was always low. Rhinos are solitary animals with wide home ranges.

A female rhino gives birth to only one calf at a time. The gestation period is about 16 months and the interval between births is thought to be 4-5 years. These long periods of time make it even harder for the species to recover from the heavy hunting pressure.

The largest surviving population of rhinos in Borneo is in the Tabin wildlife reserve, which is outside the HoB boundaries. Rhinos are still found in and around the Danum valley conservation area. This population might be viable if the conservation efforts are successful.

There may be scattered individuals in other interior parts of Kalimantan. Every now and then an unconfirmed sighting of a rhino is reported. It is very unlikely that these represent any viable population.

First-ever camera trap photo of a Sumatran rhinoceros in the wild on the island of Borneo. The camera trap had been set up by the WWF AREAS program in Sabah. The rhinos found on Borneo are considered to be a separate subspecies (Dicerorhinus sumatrensis harrissoni) from the rhinos on Sumatra and mainland Malaysia. The rhino is believed to be one of a population of as few as 13 individuals.
Photo: © WWF-Malaysia/Raymond ALFRED

Under pressure from nature and man

Rhinos were already rare in Borneo before recent times, so their optimum habitat requirements are unknown. Most likely, like other large mammals in tropical rainforests, they do best in dipterocarp-poor forests on fertile lowlands.

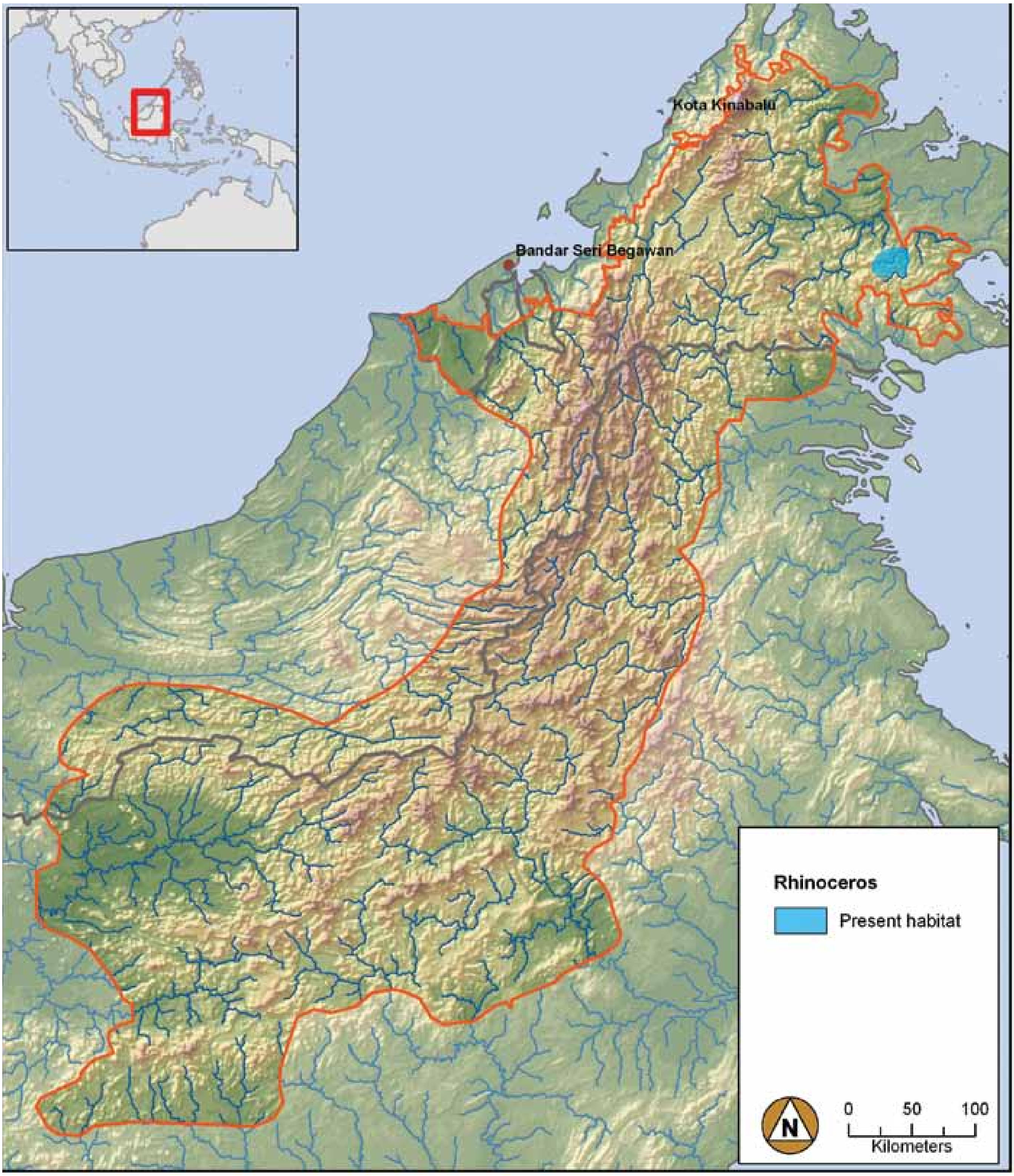
The fact that the ecologically similar Javan rhino and Malay tapir became extinct in Borneo before the expansion of the human population suggests that natural factors may have played a role in the low population density of rhinos.

The extremely low rhino population in Borneo, not habitat loss, is now the biggest threat to the species' survival. Factors associated with low numbers (difficulty or impossibility of finding a fertile mate, inbreeding, locally skewed sex ratio, etc) are driving numbers down to the extent that death rates may exceed birth rates even in suitable habitat and without poaching.

At least half the 20 or so female Sumatran rhinos caught in Indonesia and Malaysia between 1984 and 1995 had reproductive tract pathology, a phenomenon associated with lack of breeding. Fewer than 40 rhinos are believed to survive in Borneo. If about half are females, and some are too old or too young to reproduce, perhaps only six or seven rhinos are reproductively active in the entire island. With a birth interval of three years under optimum conditions, no more than two rhinos are being born annually.

Sabah now has a policy not only of preventing poaching, but also of establishing a managed sanctuary where fertile females and male rhinos can be concentrated to boost birth rate.

– Junaidi Payne


Kota Kinabalu
Bandar Seri Begawan
Rhinoceros
Present habitat
N
0 50 100
Kilometers

Clouded leopard: protected areas and habitat

Viable populations of clouded leopards require not just a minimum area but, perhaps more importantly, also large blocks of forests in good condition that are not interrupted by cultivation. This makes clouded leopards a good indicator of internal forest connectivity.

While such conditions are generally good in the HoB, in West Kalimantan much of the forest has disappeared or remains only in small, unconnected areas. Central Sabah has also seen much conversion into plantations of rubber, pulp wood and oil palm.

Although indications are that clouded leopard densities are highest in lowland rainforests, this carnivore species can live well in upland and even montane ecosystems, as long as there is sufficient prey.

The large protected areas within the HoB should harbour relatively large populations of clouded leopard. This is quite difficult to prove as surveying this cautious animal is complicated. The protected area status does not, in reality, completely protect the clouded leopard. Local people can still enter these areas in search of forest products. Their primary targets are species for consumption meat, such as bearded pigs and deer. However, if they come across a clouded leopard, it is considered an opportunity to kill the animal for its valuable skin and fangs.

A solitary predator

Clouded leopards are the top predator of Borneo, feeding on monkeys (which they usually hunt in the trees) as well as mouse deer, barking deer, young bearded pigs and sambar deer, which are stalked on the ground or jumped upon from tree branches. Occasionally birds and reptiles (such as monitor lizards) are eaten as well.

Morphological as well as DNA analysis has shown that the clouded leopard from Borneo and Sumatra is a separate species from the mainland species (Buckley-Beason et al, 2006; Kitchener et al, 2006). The Borneo species was reclassified as *Neofelis diardi*; the mainland species is *Neofelis nebulosa*.

Adult clouded leopard are solitary and each animal occupies its own territory. Interaction between adult clouded leopards occurs only during the mating season. The female gives birth to 1-5 kittens, after a gestation of 90-100 days. The young animals are independent after nine months and have to find their own territories.

The clouded leopard is a secretive animal, always avoiding humans, and thus not often encountered. It spends much of its time in the tree canopies and is more active at night than during daytime.

Relatively few records exist, and these are mainly from areas in Borneo where long-term research programs are conducted. Direct sightings of the clouded leopard are rare but camera traps are often successful in confirming their presence. Footprint recognition is only possible at sites of uncovered soil, a condition not often found in the densely vegetated interior of Borneo.

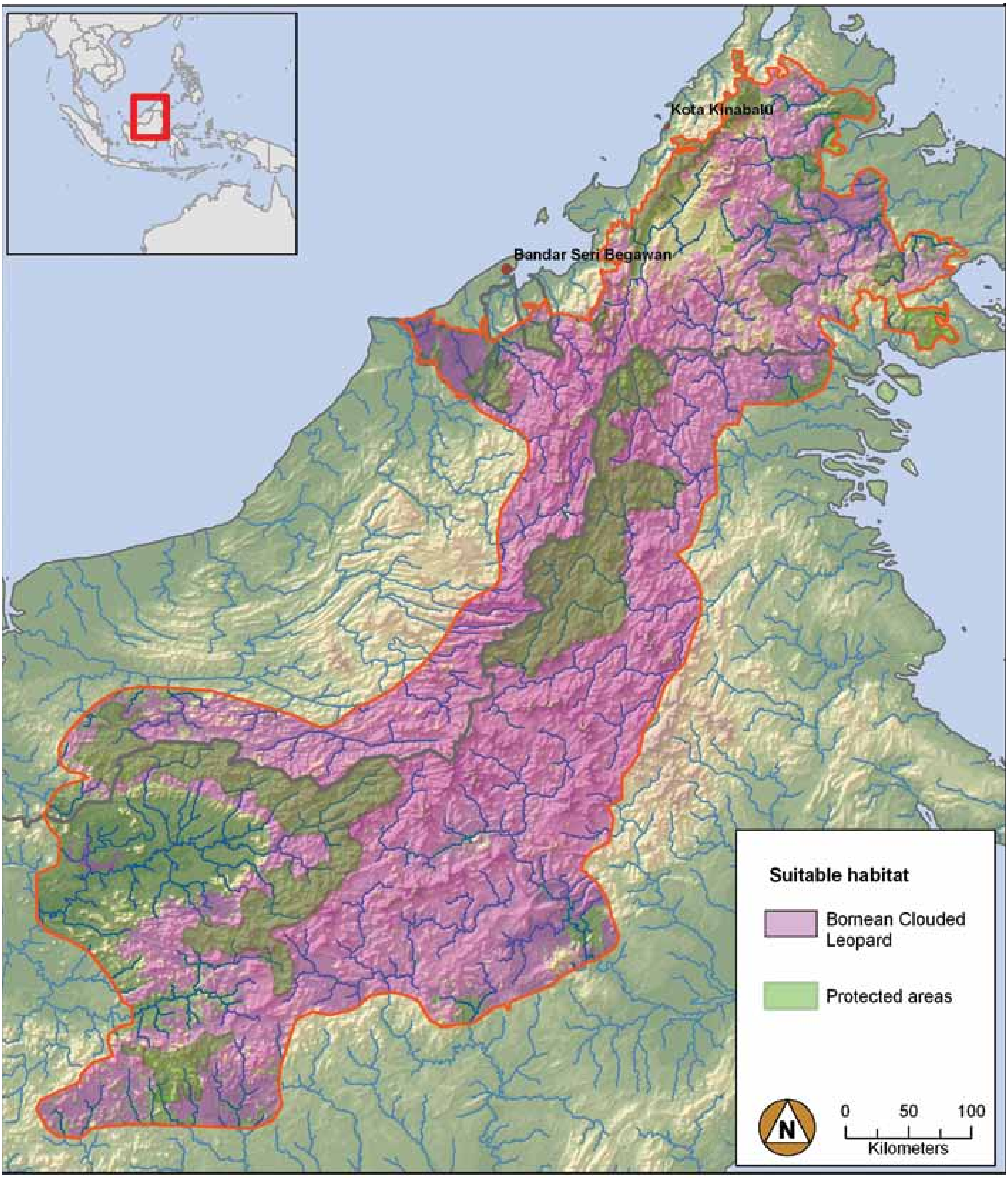
It is assumed that clouded leopards live in all areas that provide suitable habitats and where hunting pressure is absent.

It is generally accepted that a population of larger carnivores should comprise at least 50 individuals. Recent research (Wilting et al, 2006) revealed with 95% confidence that an area of 100 km^2 is occupied by 8 to 17 individuals. A safe estimate for a minimum area for 50 clouded leopards is therefore at least 500 km^2.

The areas should ideally be uninterrupted blocks of primary or older secondary forest. Vital clouded leopard populations will most likely not survive long in disturbed habitats. The upper elevation range is around 1500 metres above sea level, although individual clouded leopards may occasionally wander to even higher locations.

– Stephan Wulffraat

Clouded leopard in Central Kalimantan. Photo: © Alain Compost


Kota Kinabalu
Bandar Seri Begawan
Suitable habitat
Bornean Clouded Leopard
Protected areas
N
0 50 100
Kilometers

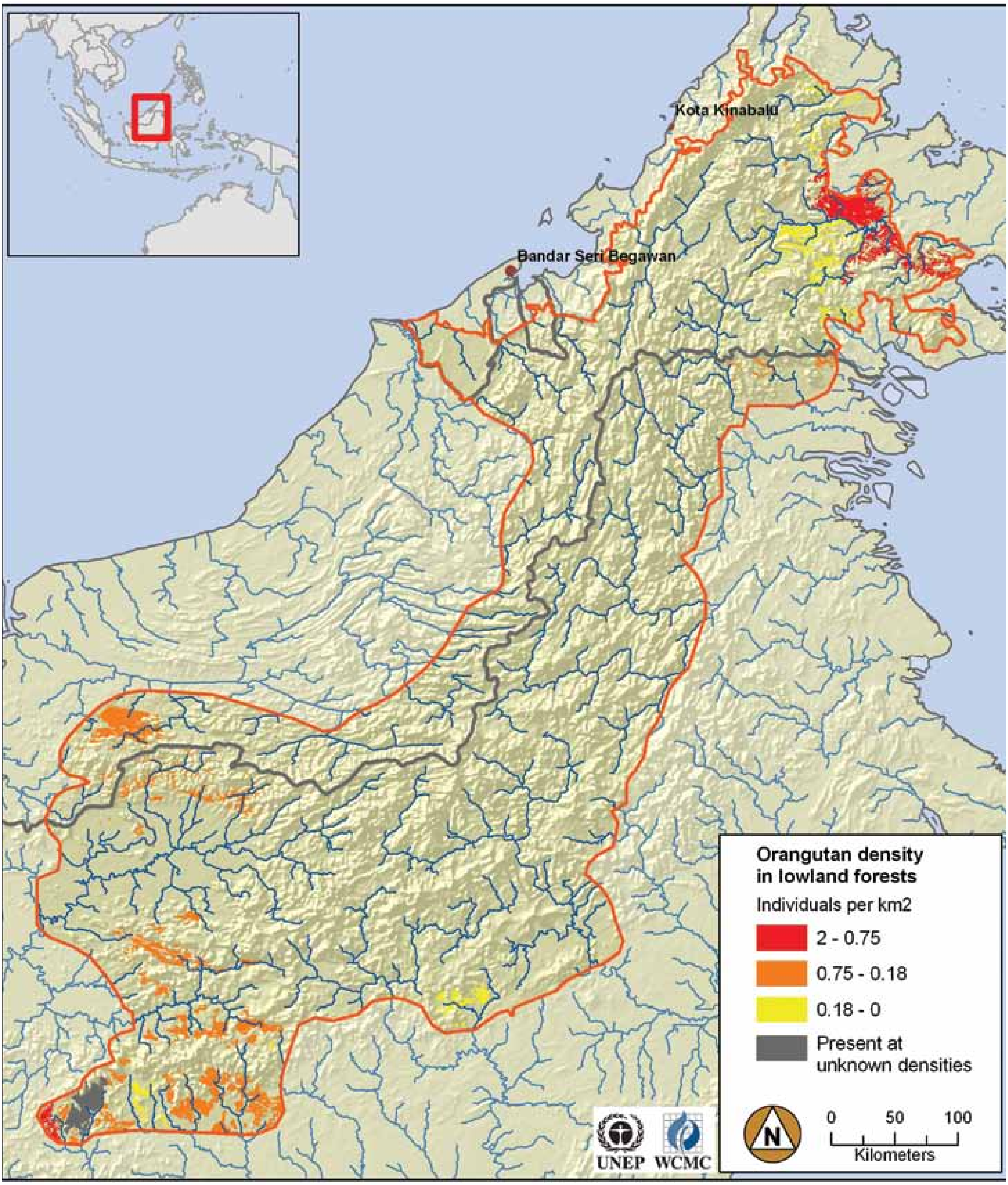
Orang-utans in lowland rainforest ecosystems

Orang-utans are present in most of the lowlands of the HoB. The highest densities are found in the middle and lower Kinabatangan area in Sabah. Densities in West Kalimantan are quite high as well, meaning one or two orang-utans per square kilometre, and there are wide connected orang-utan habitats in the north.

The Arut Belantikan area in the south of West Kalimantan has locally very high densities; part of the population is not yet known thoroughly, but this gap is being filled by current surveys in this area.

The orang-utan population in the lowlands within the HoB of Central Kalimantan has a very low density, probably due mainly to former hunting pressure. Communities in this area no longer hunt orang-utans and the potential of these lowlands for reintroduction of orang-utans is being investigated.

Seed dispersal by orang-utan, West Kalimantan.
Photo: Sugeng Hendratmo

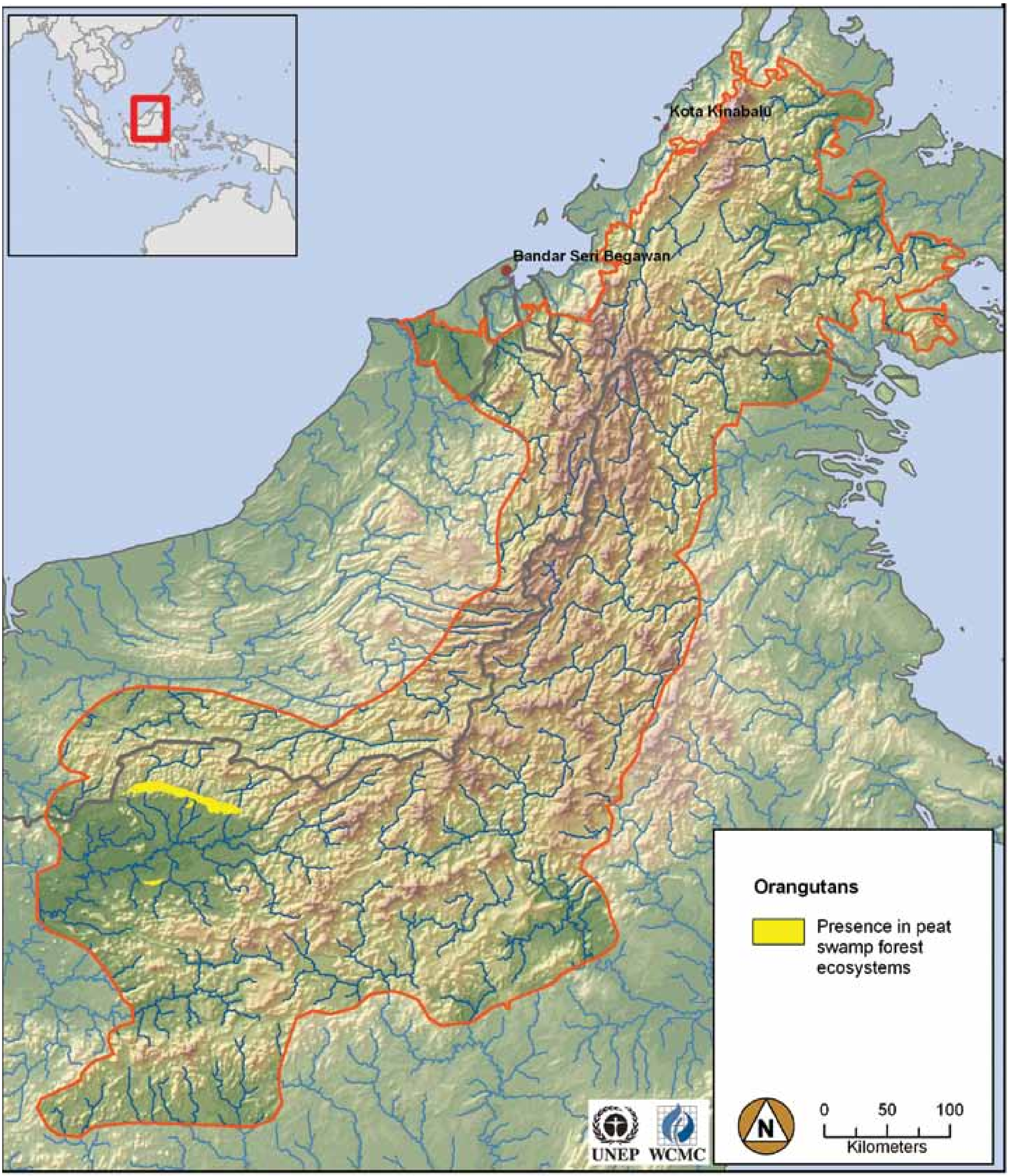

Kota Kinabalu
Bandar Seri Begawan
Orangutan density in lowland forests
Individuals per km2
2 - 0.75
0.75 - 0.18
0.18 - 0
Present at unknown densities
UNEP
WCMC
N
0
50
100
Kilometers

Orang-utans in peat swamp forest

The peat swamp forests within the HoB are mainly in the Danau Sentarum area of West Kalimantan. This is an important orang-utan habitat, particularly the northern part. The peat swamp forests north of the lakes used to be connected to lowland and upland rainforest habitats of Betung Kerihun National Park. Forest conversions have cut these connections in most locations, but conservation activities are ongoing to safeguard at least a connecting corridor.

Peat swamp forests are very important orang-utan habitats. The extensive peat swamps of Sebangau National Park harbor some of the highest numbers of orang-utans in the world.

Orang-utan in the canopy, Central Kalimantan.
Photo: Stephan Wulffraat


Kota Kinabalu
Bandar Seri Begawan
Orangutans
Presence in peat swamp forest ecosystems
UNEP
WCMC
N
0
50
100
Kilometers

Orang-utans in protected areas

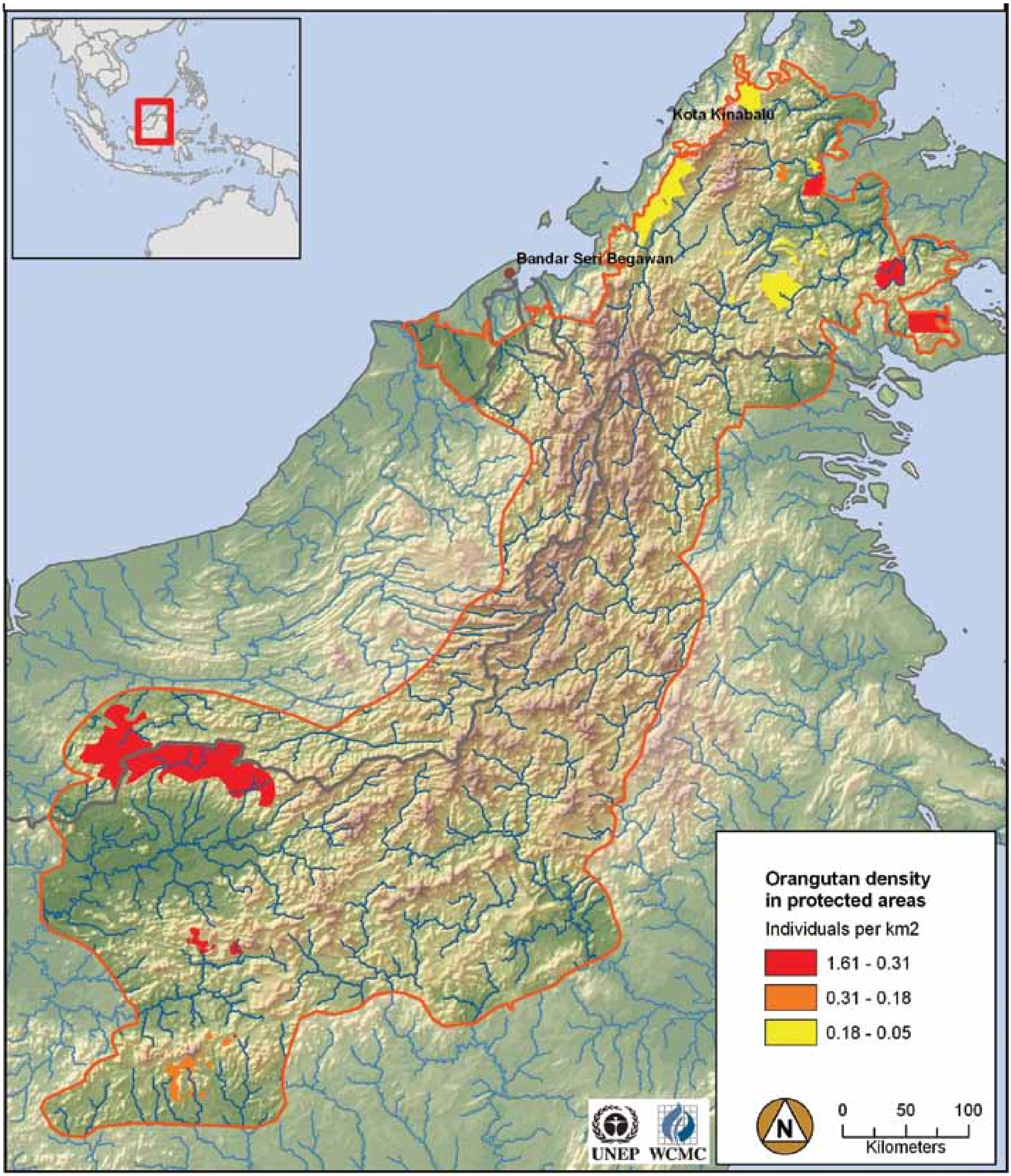
The majority of the protected areas of the HoB are at higher elevations. A number of these include lowland rainforests, usually in the river valleys at the edges. Protected areas in Sabah such as Crocker Range and Kinabalu support small populations of orang-utans, perhaps because of the mix of Dipterocarp and lower montane forests which provide peaks of fruit abundance at different times of the year.

Betung Kerihun National Park and the connecting Lanjak Entimau Wildlife Sanctuary in Sarawak have considerable areas of lowland rainforests and rich upland rainforests with many valleys. There is a large orang-utan population here and densities are quite high. Orang-utans in Danau Sentarum National Park will be reconnected to them.

There are not many other protected areas with orang-utans. For example, there are no longer orang-utans in Kayan Mentarang, the largest protected area of Borneo.

Most of Borneo's orang-utans do not live in protected areas. This makes it very important that additional conservation initiatives are implemented. Some places have quite a few orang-utans that are apparently surviving, even in logged and burned forests. Oil palm plantations are the biggest threat, unless these are willing to set aside areas for orang-utans and other wildlife (R. Steubing, pers. comm.). Chances to establish new protected areas in lowlands are small and will often require collaboration with logging companies and oil palm plantations that might be willing to incorporate some orang-utan conservation in their management practices.

A fresh orang-utan nest (sleeping place) in Danau Sentarum National Park, West Kalimantan. Photo: Sugeng Hendratmo


Kota Kinabalu
Bandar Seri Begawan
Orangutan density
in protected areas
Individuals per km2
1.61 - 0.31
0.31 - 0.18
0.18 - 0.05
N
0
50
100
Kilometers
UNEP
WCMC

Endemic Nepenthaceae

Most of the 24 endemic *Nepenthes* (pitcher plant) species of Borneo have a very limited distribution. A number are found only around the summits of the highest mountains; others have a wider distribution, but are restricted to fragile habitats such as heath forests or limestone ecosystems. Their very specific habitat requirements make the endemic Nepenthaceae a suitable indicator species to provide an insight into the conditions of fragile ecosystems in the HoB.

Nearly all the high-concentration areas of endemic *Nepenthes* species are within the HoB boundaries. Some habitats are within protected areas; others are sites that are generally not suitable for agriculture, making the threat of habitat conversion less of an issue.

However, even within protected areas the habitats need special attention as disturbances by visitors and illegal collectors still occur. The status of the endemic pitcher plants in a protected area serves as a good indicator for management effectiveness.

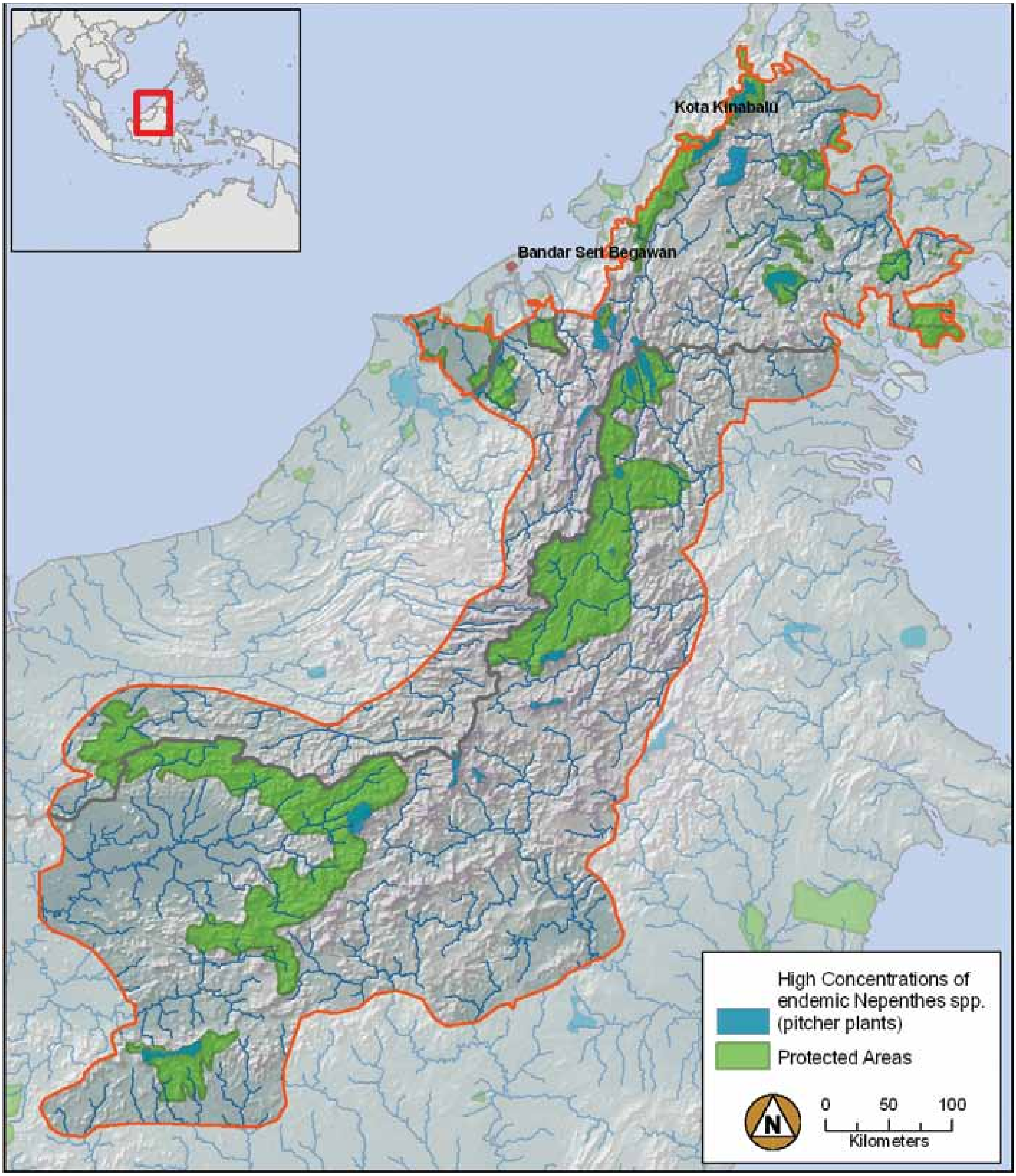
The collection of plants for the international trade is a major threat to endemic *Nepenthes* species in areas without protected status. This is a major issue that has led to the near extinction of *Nepenthes clipeata* in the wild.

Kinabalu Park is the most important area for endemic Nepenthaceae. Recent surveys in large protected areas such as Kayan Mentarang and Betung Kerihun however have shown that these locations also harbor several endemic *Nepenthes* species.

Nepenthes clipeata, a rare endemic pitcher plant species that can only be found at Bukit Kelam, West Kalimantan. Photo: Sugeng Hendratmo

Nepenthes villosa. Upper slopes of mount Kinabalu. Photo: Stephan Wulffraat

Nepenthes veitchii. Kayan Mentarang, East Kalimantan. Photo: Stephan Wulffraat


Kota Kinabalu
Bandar Seri Begawan
High Concentrations of endemic Nepenthes spp. (pitcher plants)
Protected Areas
N
0 50 100
Kilometers

Pitcher perfect

The Heart of Borneo is likely the world's most important area for rare *Nepenthes* (pitcher plants). Twenty-four species of *Nepenthes* grow only in Borneo, many with a very limited distribution, such as the summits of high mountains.

Six species are found only at Mt Kinabalu or a few other high mountains in Sabah. One of these is *N. rajah*, which is the largest pitcher in the world, able even to trap rats. It grows only in a few highland valley areas of Mt. Kinabalu. *Nepenthes vilosa* is also restricted to Mt. Kinabalu but can be seen in many locations there.

Other mountain summits that have one or more endemic *Nepenthes* species include Gn. Mulu, Gn. Murud and Gn. Trus Madi.

Nepenthes Rajah. Photo: (c) WWF-Malaysia/ Dionysius Sharma

Mountain summits of Malaysia have been explored more intensively than those in Indonesian Borneo and a number of species that are so far only known from a few mountains in Sabah or Sarawak might also occur on mountain summits of Kalimantan. *N. lowii* for instance was also found in Kayan Mentarang during surveys in the 1990s. This is one of the most remarkable species, with pitchers in the shape of trumpets.

Several species are restricted to limestone habitats. The isolated limestone ridges of East and South Kalimantan and Sarawak harbour some species that are have not been found anywhere else.

The most vulnerable species are those found only in a single location. *N. mollis* is only known from Mt Kemul in East Kalimantan, *N. boschiana* has only been found on Gn. Besar in South Kalimantan and *N.s murudensis* is only known from the summit of Mt Murud. The first two locations are not part of a protected area.

Probably the rarest and most endangered species is *N. clipeata*, which is known only from a single location, Bukit Kelam in Sintang district of West Kalimantan.This area is not protected but has the status of recreational forest. Specimens of *N. clipeata* have been collected extensively for trade, often to international destinations. During a recent survey it was found that there are only five plant clusters left (Albertus Tjiu, pers. comm.).

N. campanulata was thought to be extinct. It was known from only one location in East Kalimantan which was destroyed by forest fires in the 1980s. All that was left were a few dried specimens (collected in 1957) stored in herbaria. In 1997, however the species was rediscovered in Mulu National Park.

Not all endemic pitcher plants are extremely rare. Some species have a widespread but patchy distribution in large parts of Borneo, where they grow mainly in montane forests or in heath forest ecosystems. A species such as *N. veitchii* is found in Sarawak and the northern part of West Kalimantan, but also in Maliau Basin in Sabah and some locations in Kayan Mentarang. The pitchers of this attractive species develop a wide collar and have a wide variety of colours.

Opposite: Nepenthes Rajah. Photo: (c) WWF-Malaysia/Azwad MN

Endemic Fagaceae and Dipterocarpaceae

Dipterocarpaceae

Borneo has more than 150 tree species from the Dipterocarpaceae family found nowhere else in the world. Most are in lowland rainforests and most of the lowlands outside the HoB have been intensively logged; some of the last untouched (primary) lowland rainforests of Borneo are inside the HoB. Of special interest are the lowlands of Central Kalimantan, Brunei and Danum valley and its surroundings. It is here that many of the endemic Dipterocarpaceae species are found, adding another conservation priority to the HoB importance.

Species of the Dipterocarpaceae family are usually much sought after, having high commercial value, and timber companies do not distinguish between common and rare endemic species. Species are grouped together based on the characteristics of their wood, particularly specific weight and colour. A group like 'light red meranti' can include tens of different species, some quite rare.

Although each of the family's nine taxa has at least one species endemic to Borneo, the taxon *Shorea* tops the list with some 90 endemic species. The monotypic taxon *Upuna* exists only in Borneo, represented by its only species *Upuna borneensis*.

Anisoptera – 2 endemic species

Cotylelobium – 1 endemic species

Dipterocarpus – 12 endemic species, 2 endemic sub-species

Dryobalanops – 5 endemic species

Hopea – 22 endemic species, 2 endemic sub-species

Parashorea – 4 endemic species

Shorea – 86 endemic species, 5 endemic sub-species

Vatica – 22 endemic species, 1 endemic sub-species

Upuna borneensis – the genus *Upuna* is monotypic and exists only in Borneo.

Fagaceae

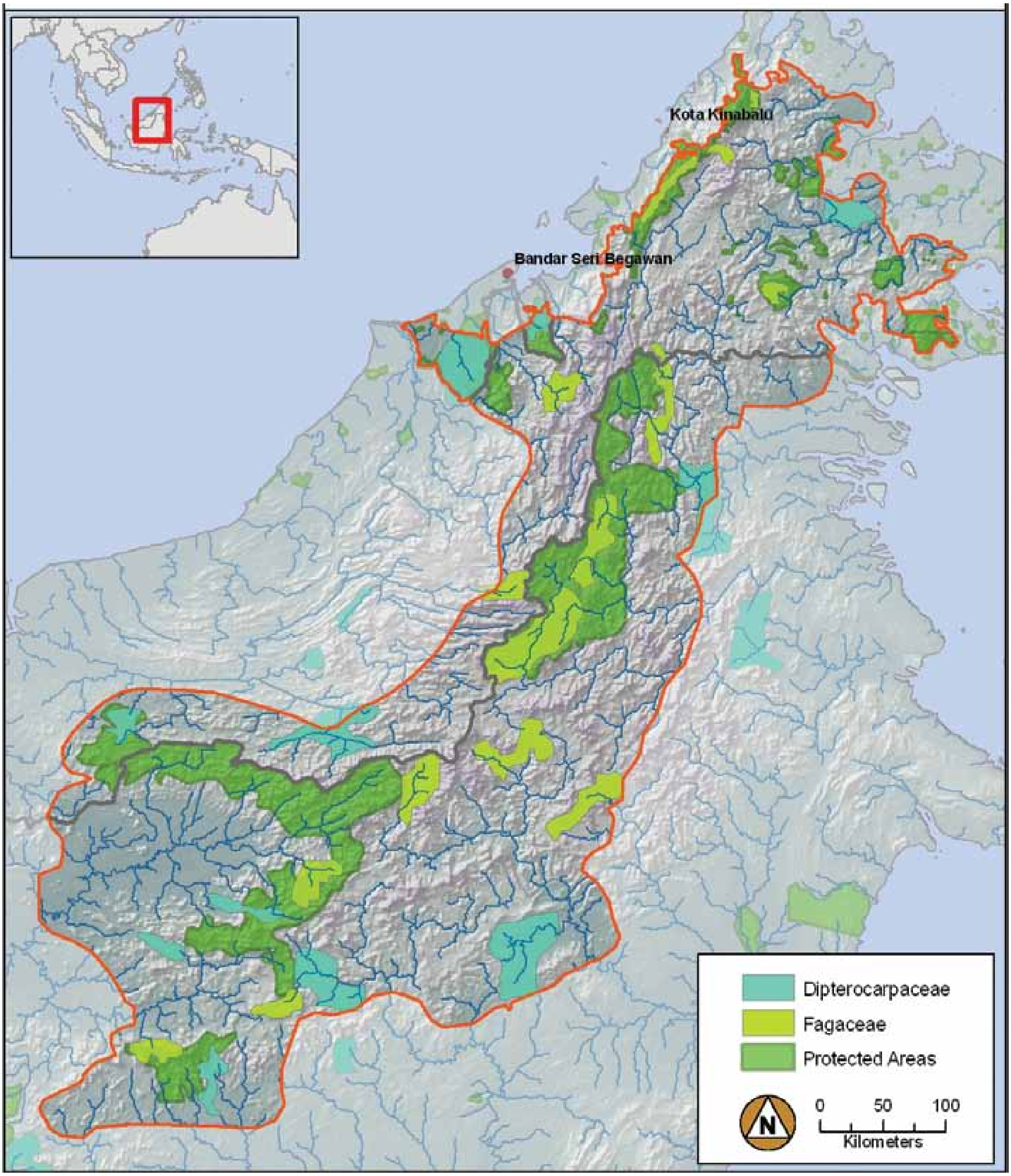
The Fagaceae is a family consisting mainly of trees with a worldwide distribution. It includes the beeches (*Fagus* spp.), chestnuts (*Castanea* spp.) and oaks (*Quercus* spp.) that are important species in the temperate forests of Europe and America. In Borneo, the family includes tropical chestnuts (*Castanopsis* spp.) as well as two taxa of tropical oaks (*Quercus* and *Lithocarpus* spp.). Borneo has more than 40 endemic Fagaceae species (*Castanopsis* 10 spp, *Lithocarpus* 26 spp, *Quercus* 8 spp.) *Trigonobalanus*, although not endemic, is a rare taxon, considered an evolutionary missing link within the family, and one of its most important distribution areas is the HoB.

Most of the endemic Fagaceae are found in the uplands and montane areas of Borneo.

The majority of the species is most likely represented in protected areas of the HoB, particularly Kinabalu, Crocker range, Kayan Mentarang and Betung Kerihun. Pressure on these species is not as high as on the endemic Dipterocarpaceae as most do not have a high commercial value.

Lithocarpus fruits. Photo: Stephan Wulffraat

Shorea seedlings at the forest floor in Danau Sentarum National Park. Photo: Sugeng Hendratmo


Kota Kinabalu
Bandar Seri Begawan
Dipterocarpaceae
Fagaceae
Protected Areas
N
0
50
100
Kilometers

Watershed analysis

Island-scale watershed vulnerability analysis

Following the measures work to evaluate the Heart of Borneo (HoB), the biological, physical and anthropogenic characteristics of island-wide watersheds were assessed for their land-based threat to water quality and downstream coral reefs.

Rivers draining into the sea carry sediment, pollutants and other products of erosion, runoff related to agriculture, industry and development. Terrestrial pollutants – often from chemical fertilisers and pesticides – are increasingly found in rivers, and ultimately coral reefs and marine sediments, indicating a clear link between activities on land and marine ecosystems. Activities far inland and distant from shore, such as in the HoB, can have significant impacts on marine ecosystems and sensitive coral reefs.

Watershed integrity and vulnerability to erosion and their subsequent effects on water quality are commonly modelled with a modified universal soil loss equation in a GIS.

Equation 1: RUSLE (Renard, 1997)

Average Annual Soil Loss (tons/acre) = R * K * L * S * C * P

R – Rainfall-runoff erosivity factor – derived from precipitation and elevation

K – Soil erodibility factor – based on the soil type and resistance to erosion

*L*S – Slope steepness and length factors* – based on topography and length of the distance water travels over land

C – Cover-management factor – a relative erosion rate for land cover types (natural vegetation is less prone to erosion, while agricultural lands have a higher relative erosion rate)

P – Supporting practices factor – not included in this analysis

Equation 2: Physical vulnerability to erosion = R * K * S 0.6

R – Rainfall x runoff erosivity factor

K – Soil erodibility factor

S – *Slope* (in degrees)

A complete dataset of physical terrain variables, biological variables relating to land cover, and anthropogenic data from logging, pulp and paper, and oil palm concessions were used to assess several scenarios of threat and development. Watersheds were evaluated and compared by their erosion potential based on physical characteristics of slope, watershed size and soil type. Concessions in areas vulnerable to erosion have been identified for further management or mitigation. Watersheds with the highest proportions of concessions, plantation and road density are also evaluated to identify where the main anthropogenic threats to freshwater and marine ecosystems downstream are located.

Satellite-derived water quality, notably chlorophyll concentration (related to eutrophication or a surplus of nutrients) and coloured dissolved organic matter (CDOM; related to suspended sediment, turbidity) are commonly used to identify the presence of land-based threats in marine environments. A time series of freely available SeaWifs (Sea-viewing Wide Field-of-view Sensor) imagery was analysed to identify high and anomalous concentrations of chlorophyll and coloured dissolved organic matter (CDOM) in 2007, corresponding to the land cover data available. This spatio-temporal assessment identified when and where the highest concentrations of land-based pollutants and nutrients occur around the island.

Water quality indices (maximum and standard deviation of chlorophyll and CDOM) around outflow points of contributing watersheds were spatially linked for statistical analysis. Multivariate regression models, including spatial variables to account for spatial auto-correlation, were compared to determine the strength and direction of the most important indicators for low water quality parameters. These provide a series of easily measurable proxies for identifying land-based threats to marine environments and their sensitive coral reefs. The main conclusions, correlating the major factors affecting offshore water quality were:

> *Physical*: higher modelled relative erosion rate (higher slope, precipitation, erodible soils) was associated with lower water quality as expected.

> *Biotic*: proportion of watershed area that is bare was positively correlated with poor water quality indices; increasing lowland rainforest cover was related to better water quality; greater proportion of mangrove and swamp forests were correlated with better water quality.

> *Anthropogenic*: water quality decreased with increasing number of fires (as detected by satellite).

The major recommendations for reducing the effects of land-based sources of pollution are to :

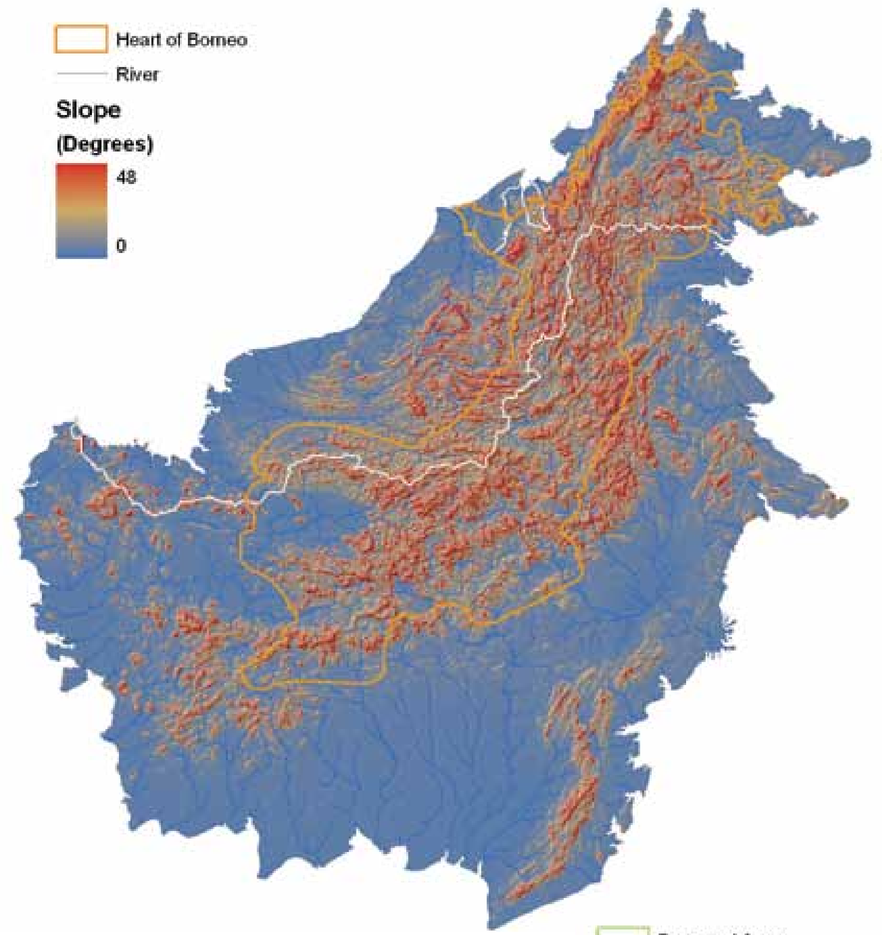
> make sensible land use planning decisions in areas that are more physically prone to erosion and runoff;

> monitor forest fire activities by satellite and observe when they occur in areas vulnerable to erosion, which are an indication of human presence and development that can result in increased erosion from vegetative cover loss; and

> maintain lowland rainforest cover, mangroves and swamp forest to regulate water flow, buffer rivers and streams and prevent sediment from attaining the marine environment.

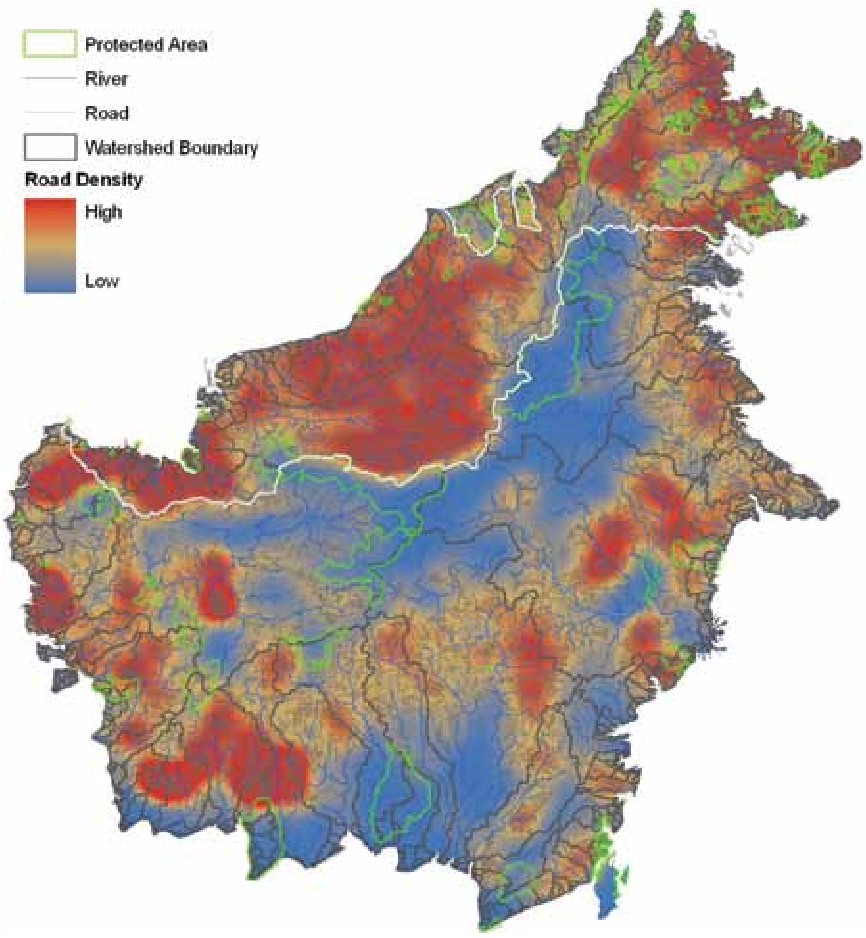
The immediate results of forest clearing are well known – loss of habitat and biodiversity – but the more far-reaching effects from erosion and runoff have not been as well studied. This project has identified the terrestrial indicators for low water quality downstream, allowing managers to effectively identify where land use practices can potentially harm coral reefs.

A summary of the most important maps produced from this analysis are included in the following pages.



Map 1. Elevation derived slope

The slope (in degrees) created from the digital elevation model shows the relief of the island. The Heart of Borneo covers the mountainous, rugged centre, coastal areas are generally flat. An important physical component of soil loss is slope – steeper land tends to be more vulnerable to erosion and should ideally remain vegetated to stabilise the soil. As such, agriculture and deforestation are generally concentrated in the coastal lowland areas.

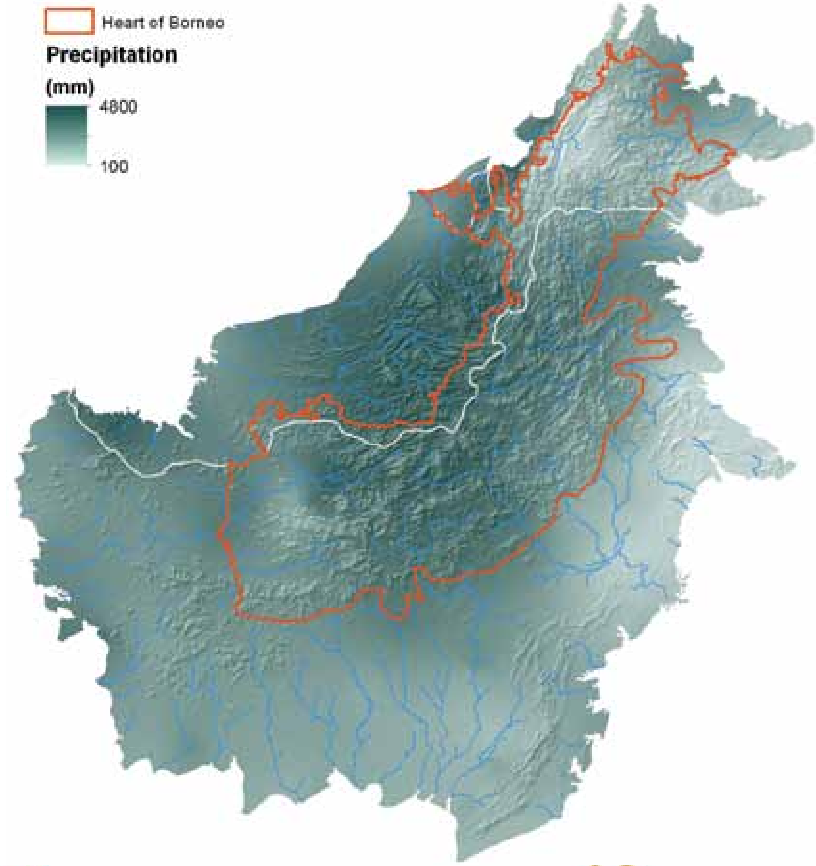


Map 2. Road density

There is a total of 266,392 km of roads on the island of Borneo according to available data from WWF. A density analysis shows areas with the highest amount of roads per km^2 area. The highest road density is in Malaysia, with pockets of high density in Kalimantan. Roads are a good indicator of human influence and forest degradation.

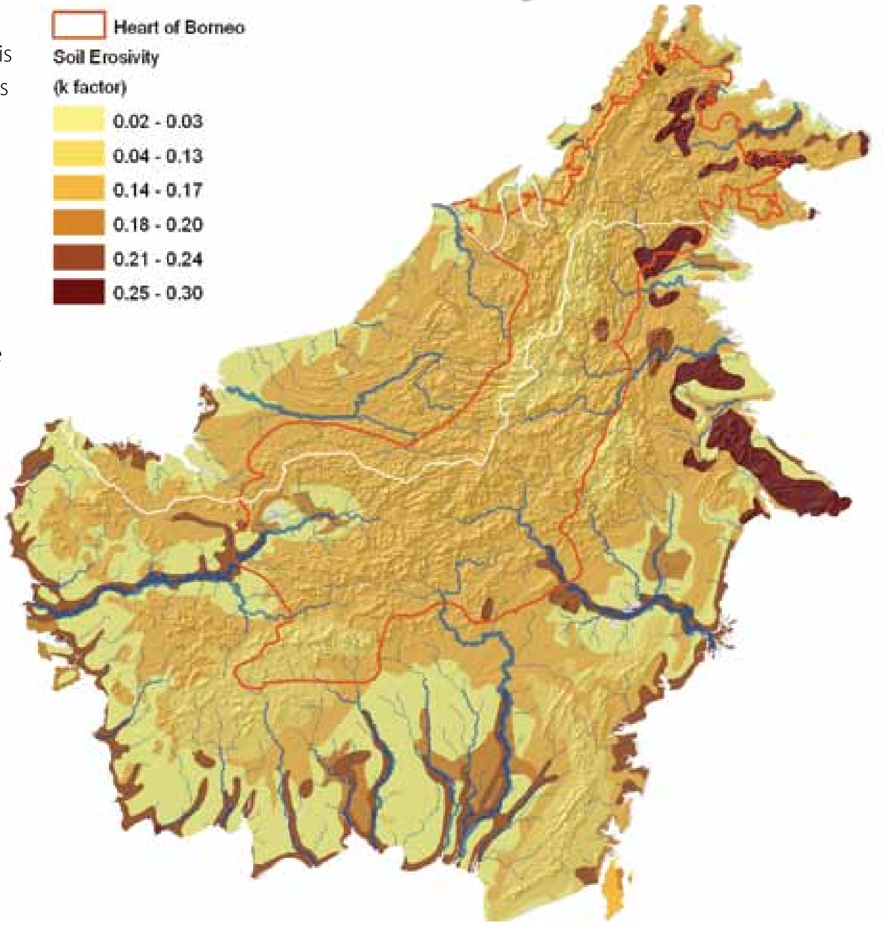
Map 3. Precipitation

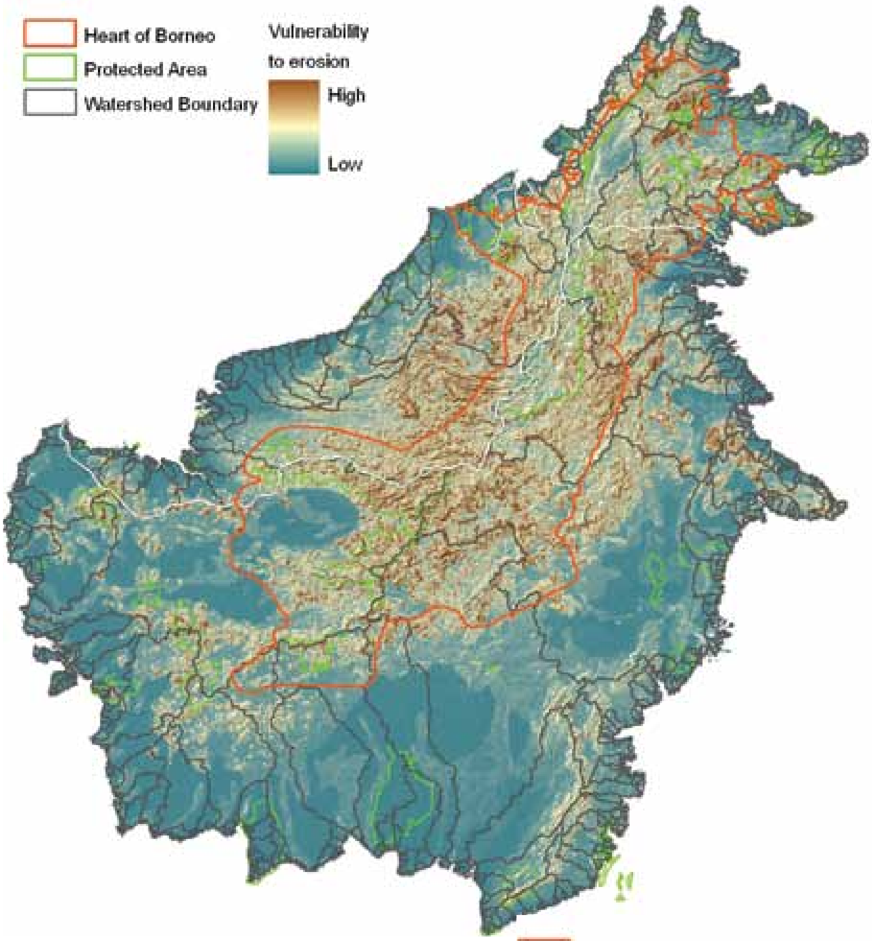
Erosion and potential soil loss modelling requires precipitation, soil parameters and topography data. Precipitation data used for the analysis was the mean annual precipitation from WorldClim (worldclim.org). Rainfall drives soil erosion, so areas with higher rainfall will likely have more soil loss, which results in sedimentation in rivers and streams.



Map 4. K factor: Soil erodibility

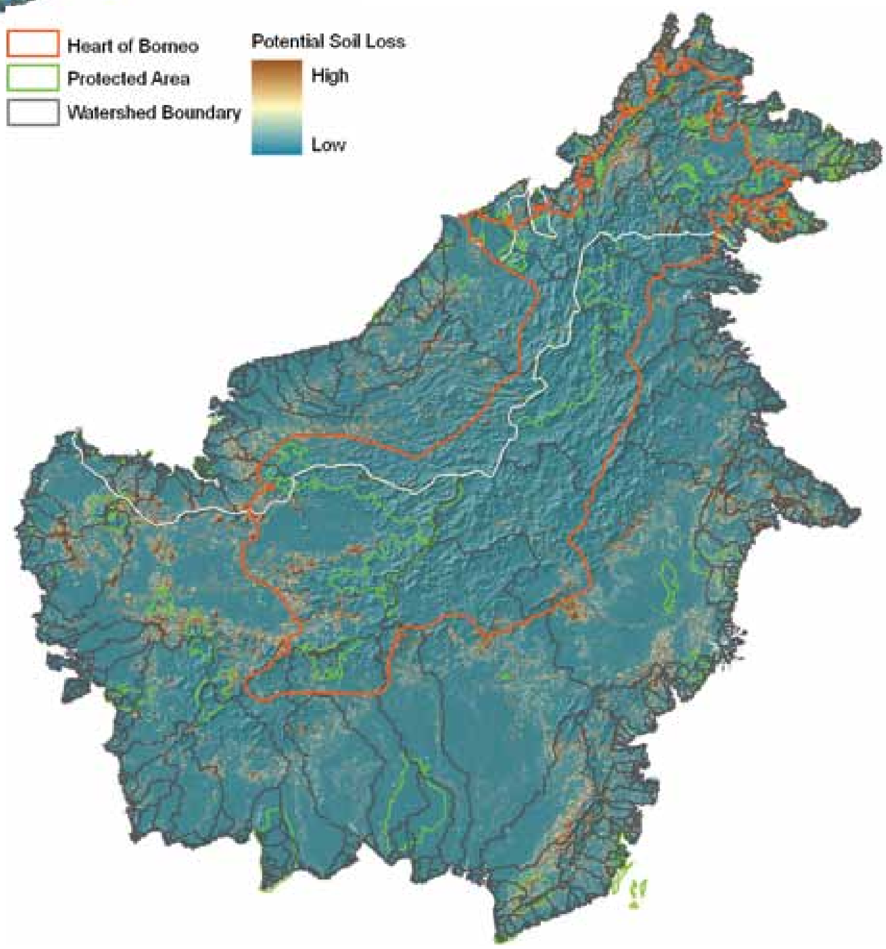
A crucial factor in determining potential soil loss is from the k factor, or soil erodibility parameter. This factor was provided by personal communication from a soil expert at the US Department of Agriculture. Clay soils tend to have a higher resistance to erosion as particles tend to stick together (k factor <0.2), whereas silty and mixed soils have higher erodibility. In Borneo, there is generally higher resistance to erosion, with a few areas of very high erodibility, especially along the eastern coast of Kalimantan.





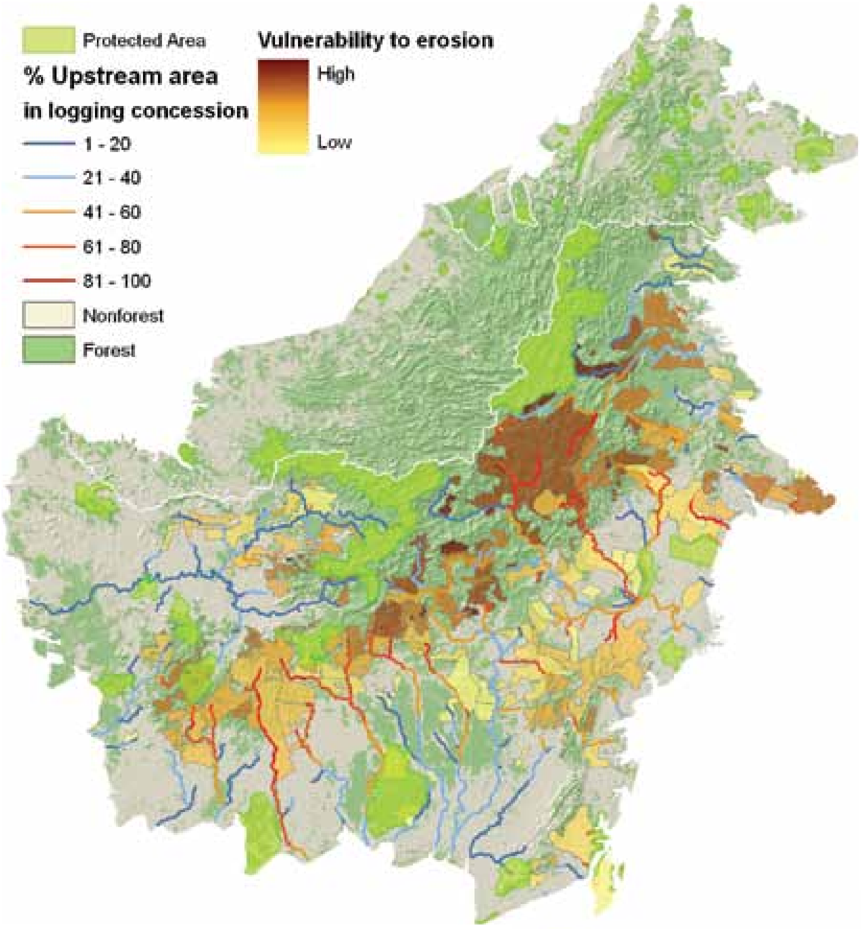
Map 5. Physical vulnerability to erosion

Vulnerability is an assessment of which areas have the physical characteristics of land to being erodible (based on slope, elevation, precipitation and soil), and where land cover conversion for agriculture should be avoided (from Burke and Sugg, 2006). The analysis of vulnerability based on physical characteristics of soil and topography show that the highly erodible areas are located primarily in the HoB. Protected areas in the central portion of the island are providing an important ecosystem service – by keeping these steep areas forested with natural vegetation, these areas are less prone to runoff or sedimentation of river systems and maintain water quality and quantity.



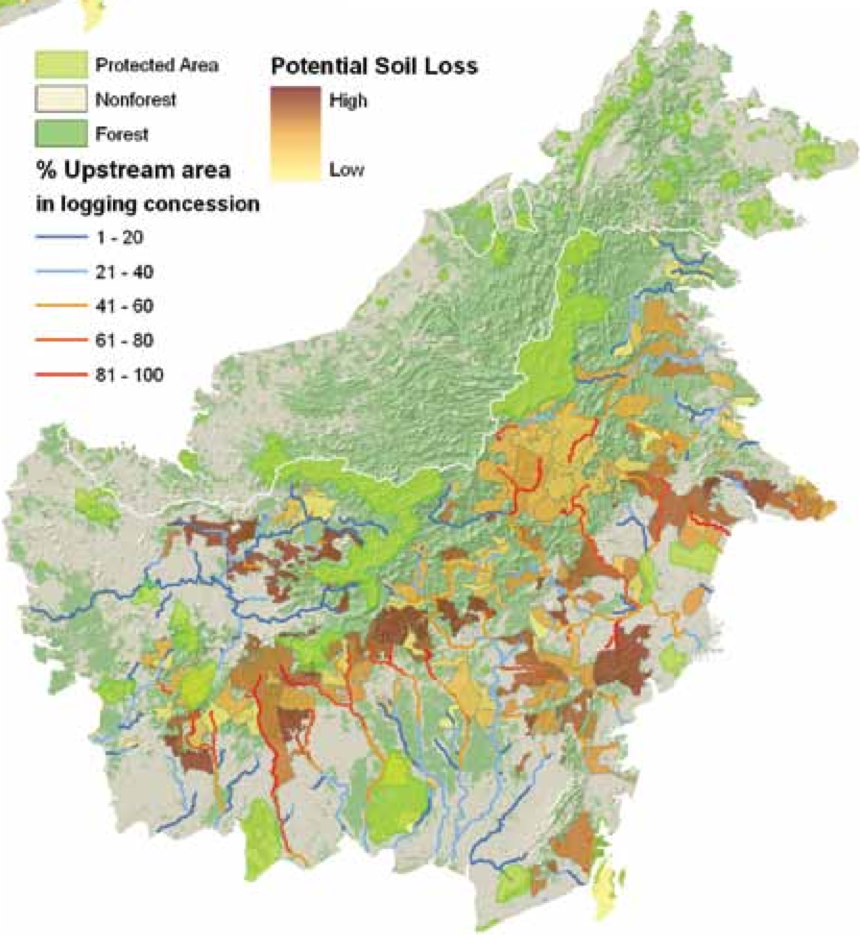
Map 6. Potential soil loss from RUSLE

Land cover is taken into account by assigning relative erosivity to land cover types and combining it with vulnerability. Natural forest cover has low erosivity while burned areas or agriculture have much higher erosion potential. Lowlands generally have high potential soil loss given their deforested state, and while the HoB is largely forested with low potential soil loss; areas in red are where recent deforestation has resulted in higher potential soil loss. These areas are good sites for restoration and erosion mitigation. Mapping soil loss potential is also useful for planning and mitigating plantations and logging concessions.



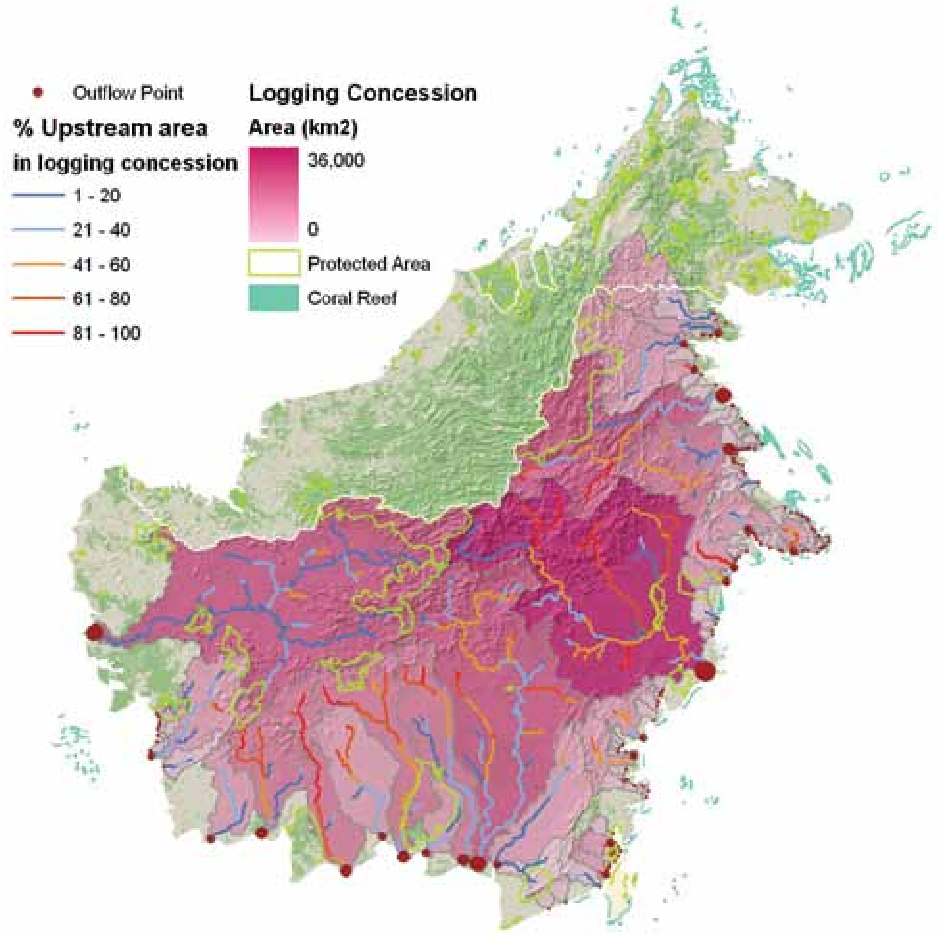
Map 7. Vulnerability of logging concessions

Logging concession data was only available for Kalimantan. This map shows logging concessions by their mean physical vulnerability to erosion (every concession is summarised by data from map 5). Regardless of current land cover, concessions in darker brown are located in areas that will be highly erodible if cleared more than selectively. Several large logging concessions are located in these areas of high vulnerability (also within the HoB) and should therefore remain forested to ensure stable soils – thus selective logging or other similar management that preserves vegetation cover would be preferable to clearing for plantations, agriculture, development.



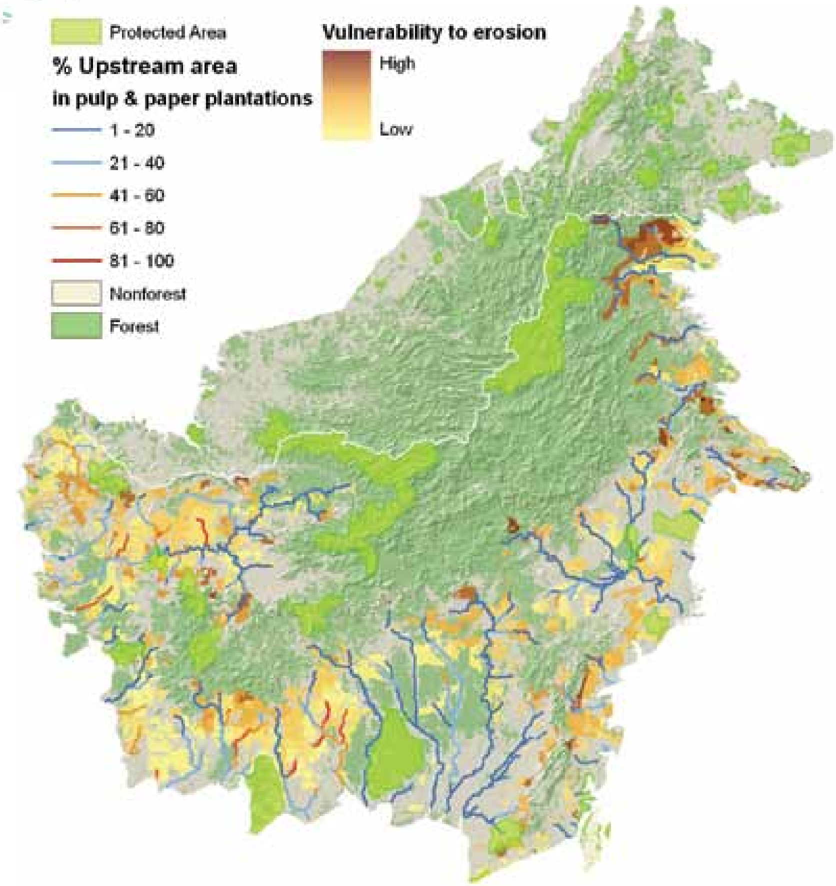
Map 8. Logging concessions shown by mean RUSLE

Darker polygons are concessions with higher potential erosion based on precipitation regime, slope, soil and land cover, so not only vulnerability is considered, but in addition the current status of these sites – darker polygons have no natural forest cover, are likely cleared or burned, and thus are exacerbating the threat of soil loss. The vulnerable concessions from the previous map have low potential soil loss – as they are still forested.



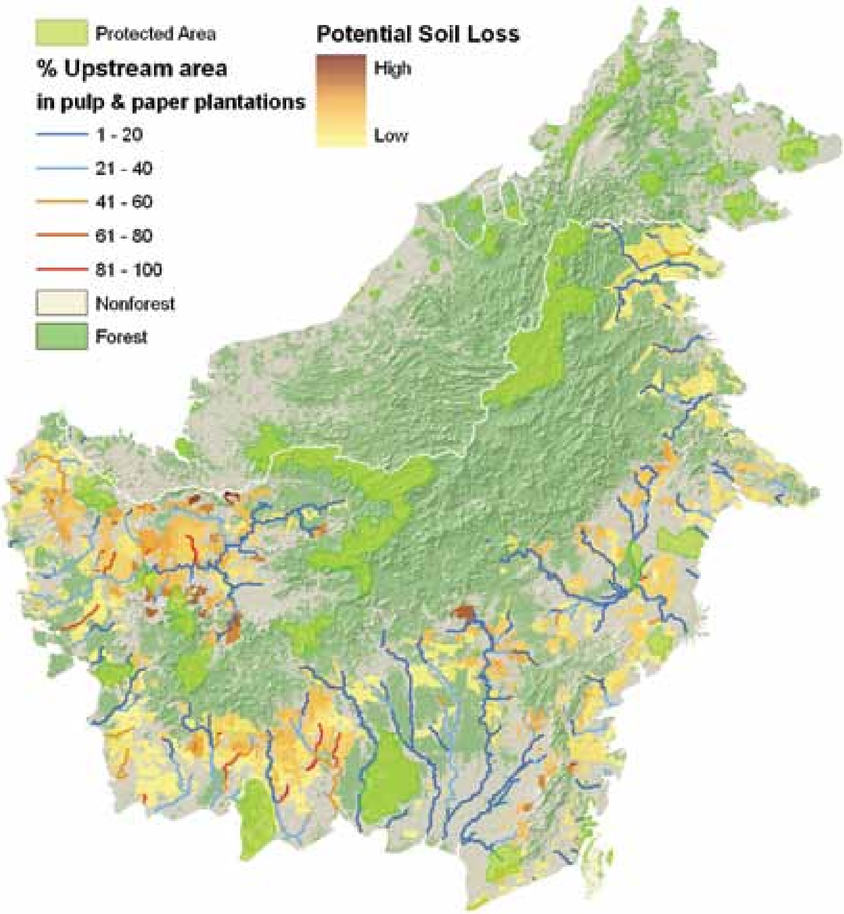
Map 9. Logging concession by watershed

Watersheds and streams vulnerable to effects of logging concessions. The size of the outflow point is proportional to the total upstream area of logging concession.



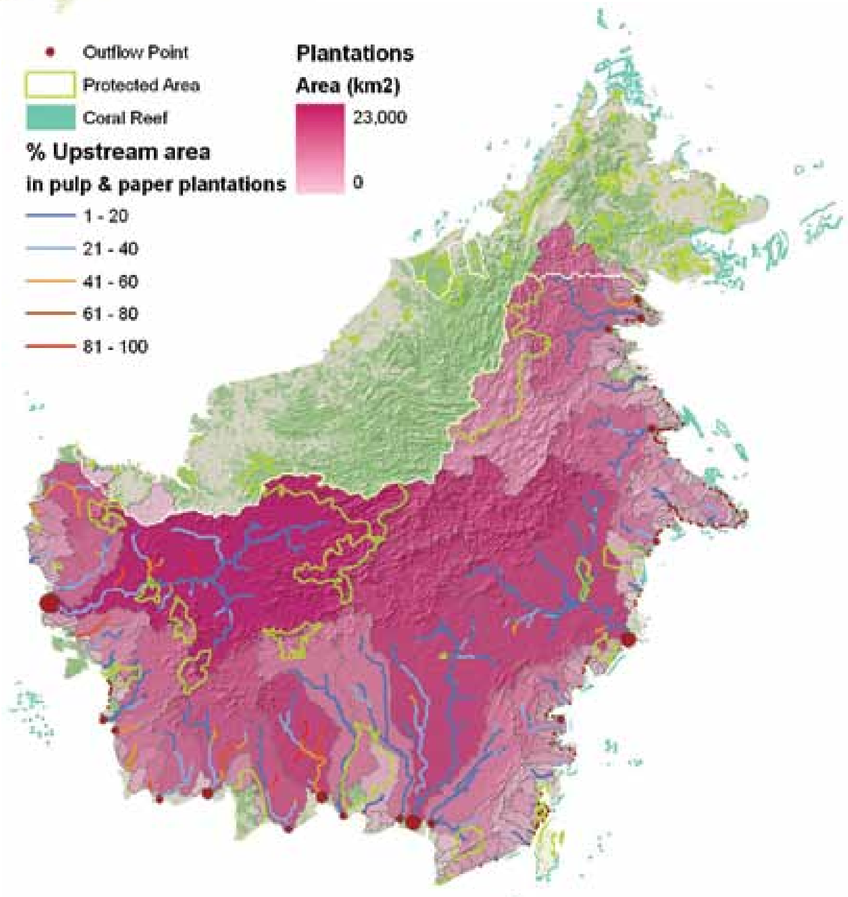
Map 10. Vulnerability of Kalimantan plantations

The plantations on the most vulnerable lands are located in northeast Kalimantan. Most downstream plantations along the coast are on flatter lands that are less erodible.



Map 11. Plantations shown by potential soil loss

Most plantations are vegetated, and therefore have less likelihood of soil loss due to exposed soil. In certain instances, remote sensing has proven some plantations are non-vegetated, either they are soon to be planted or in between harvests.



Map 12. Kalimantan plantations by watershed

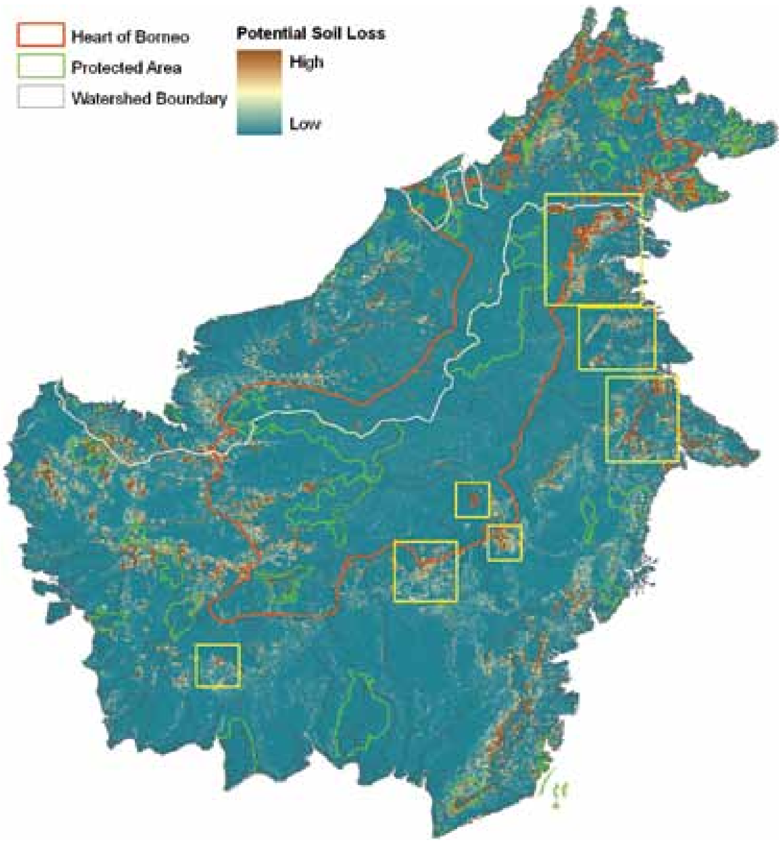
Plantations are most common in the large western Kalimantan watershed, which is also an area with a large area of swamp forest and mangroves.

Map 13. Scenario potential soil loss – plantations and selective logging

To model the logging and plantation scenario we reassign the cover factor to increase the relative erosion rate to slightly higher erosion for selectively logged forests (due to gaps in canopy, or roads) and change all natural forest areas in plantations to a cover factor for young plantations and crops. This map shows which watersheds and which rivers are affected by plantations with high potential soil loss.

The red areas highlight the differences with map 6 (RUSLE current scenario). In these areas potential soil loss is higher as a result of conversion of natural forest to plantation, which is usually achieved by complete forest clearing. In vulnerable areas this leads to high potential soil loss (and subsequently, more difficult to attain successful harvests as soil nutrients are also lost).

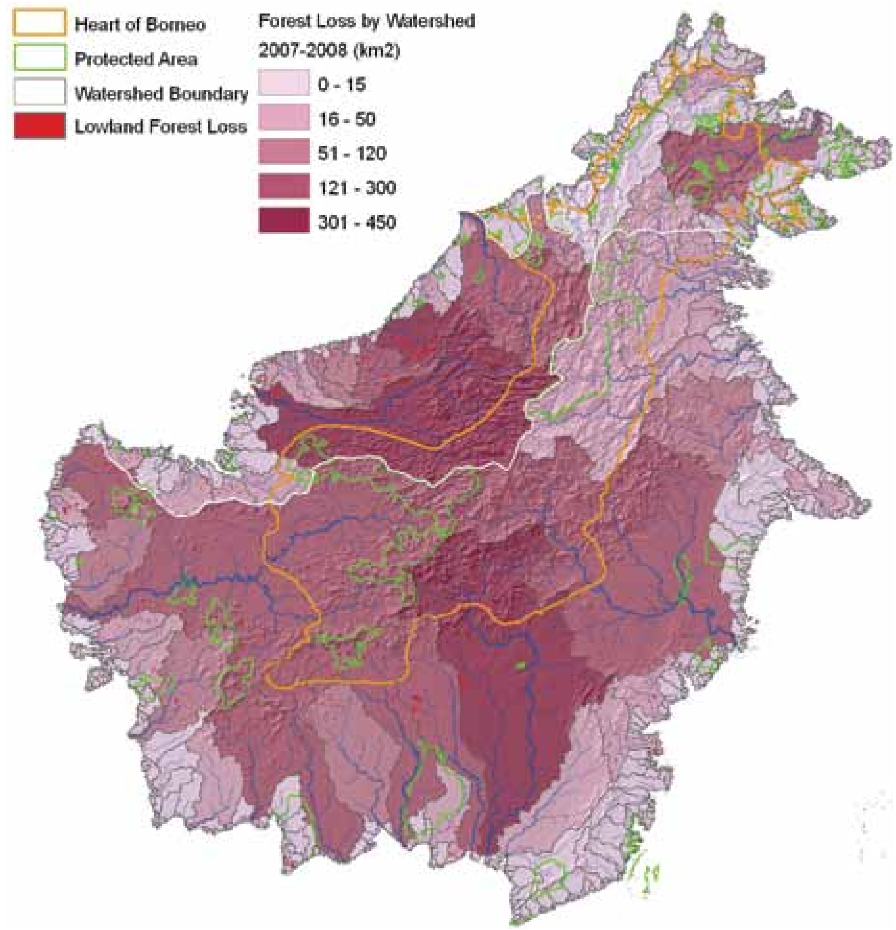
As shown in maps 10 and 11 however, only in a few cases are plantations located in areas with high vulnerability, nor do they have very overall high erosion potential. This is most likely due to the need to plant on stable slopes in order to produce efficient harvests, rather than attempting to cultivate on steep slopes with erosive soil. Therefore, the overall impacts of soil loss from natural forest conversion are pretty localised, and therefore relatively easy to mitigate.



Map 17. Loss of lowland rainforest 2007-2008

Lowland rainforest loss is one component affecting water quality that can be efficiently monitored via satellite data over time. Here, darker watersheds have greater amount of lowland rainforest loss, and therefore, according to the model would have lower water quality downstream. Monitoring forest cover change by watershed can serve as an accurate predictor to identify potential problems before impacts arise in the water.

This model can be used as an early warning system for land-based sources of pollution. Once a watershed reaches a certain threshold of the different indicators, it can be targeted for interventions to limit fires and specific actions which will likely decrease runoff, erosion and other impacts to freshwater and marine water quality.



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Appendix 1

Appendix 1 A. Biological Indicators

Target	KEA	Indicator	Justification for indicator	Long-term viability goal
Bornean clouded leopard	Distribution & densities	km^2 of suitable habitats	Top predator, viable suitable habitats also for prey species	Good (>400 km^2 forest blocks)
Orang-utan	Presence in peat swamp forests	Densities	Critically endangered species, threatened habitats	Good (1.0-1.5 per km^2)
	Presence in lowland rainforests	Densities		Fair (0.5-1.0 per km^2)
Endangered plant species	Distribution of endemic Nepenthaceae	Historical locations that are still viable	Representing fragile ecotones	Good (70 % historical locations)
Forest edge herbivores	Bornean elephant	Total population size	Endangered sub-species; directly affected by land use pressure	Fair (60% of original population, stable)
		Total population distribution		Fair (60% of original distribution, stable)
		Population connectivity		Good (>60 % of main populations connected)
		Extent suitable habitats		Good (all remaining habitats without conflict. land use retained)
	Banteng	Presence & numbers in known sites	Limited knowledge of bantengs in Borneo	
Bearded pigs	Population size	Presence/densities @ rep. sites	Monitoring this major food source is important as fewer other species are hunted as long as there are enough pigs. Group size and condition	Good (large numbers frequently passing through) Good (25-50 individuals)
Rhinoceros	Population size	Number	Critically endangered, needs permanent monitoring	Fair (50-200 individuals)
Heath forest ecosystems	Extent	% of historical	Endangered ecosystem	Good (>60% of original extent)
Peat swamp ecosystems	Extent	% of historical	Ecosystem under pressure	Good (>50 % of historical extent)
	Condition	km^2 undegraded - % canopy cover		Fair (<60% canopy cover)
Limestone ecosystems	Extent	% of historical	Endangered ecosystem; one of the main ecosystems of Borneo	Good (>60 % of historical extent)
Lowland rainforest ecosystems	Extent	% of historical	Most of this ecosystem has been converted or degraded	Good (35-50 % of orig. extent)
	Extent and condition	km^2 undegraded		Good (20-30 % undegraded)
	Size-landscape context	Connectivity between fragments	Many fragments remaining but often not connected	Good (>50% of fragments connected)
	Species composition	Tree diversity Dipt. & Fag.	Good general indicators for tree species richness	Fair (5-15 endemic Dipt./Fag. spp. per 100 ha)
Upland rainforest ecosystems	Extent	% of historical	Ecosystem under pressure, much degraded	Good (60-80 % of historical extent)
	Extent	km^2 undegraded		Good (40-60 % undegraded)
	Species composition	Tree diversity Dipt. & Fag.	Good general indicators for tree species richness	Good (15-30 endemic Dipt./Fag. spp. per 100 ha)
Montane forest ecosystems	Extent	% of historical	Fragile ecosystem	Very good (>80% of historical range)
River ecosystems	Water quality	% intact watersheds	Ecosystem under pressure	Fair (50-70% intact montane, 40-60% upland, 20-40% lowland)
	Connectivity	riparian cover 100 m buffer		Very good (>70 % riparian cover)
	Species composition	Fish species diversity		Good (>30 species per 10 km river stretch

Appendix 1B: Threat indicators.

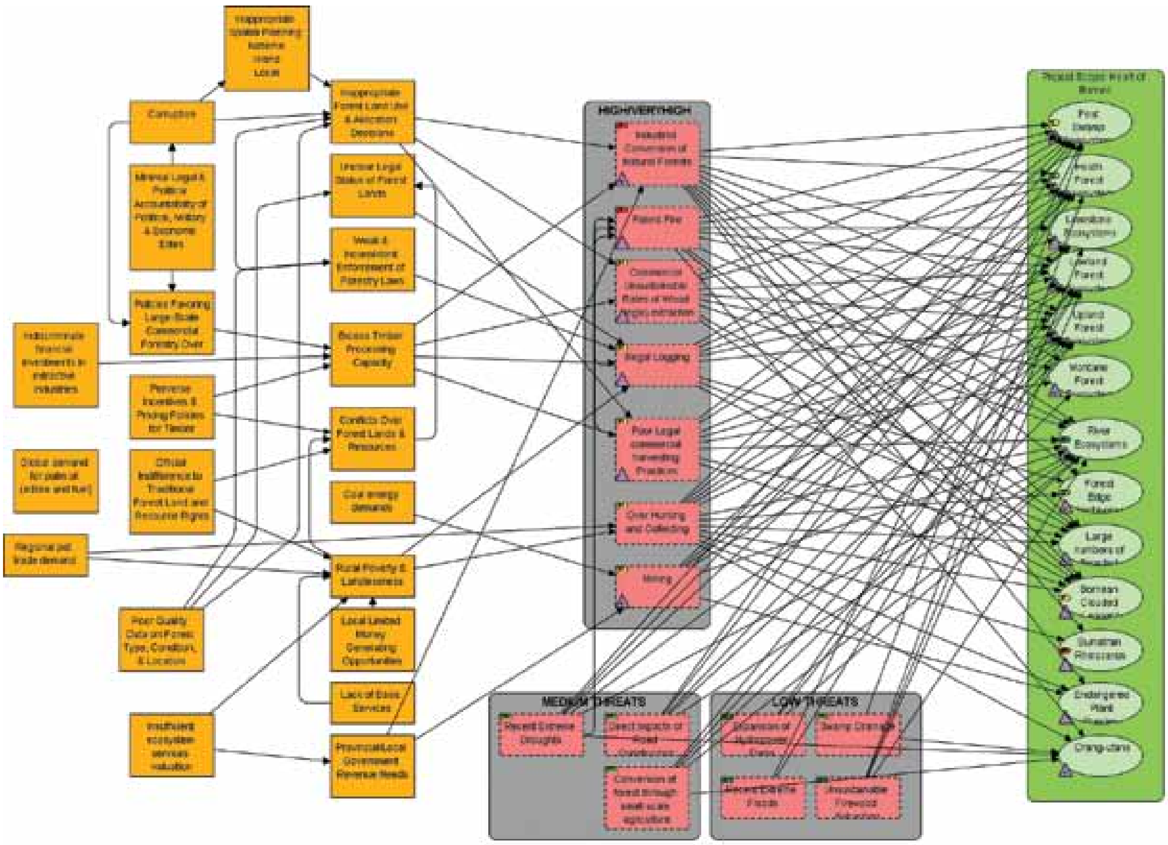
Target	KEA	Indicator	Result from Nov 2007 threat rating
Industrial conversion of natural forests	 Extent Extent & condition	Annual conversion Annual plans for conversion Forests within plantations	Very high threat
Forest fire	Incidence Incidence Incidence Incidence Incidence Incidence Incidence	Annual number and extent of fires Fires in logging concessions Fires by year Fires in heath forest ecosystems Fires in peat swamp forest ecosystems Fires in lowland rainforest ecosystems Fires in limestone ecosystems	Very high threat
Mining	Extent Extent	Existing extent Projected extent	High threat
Illegal logging	Incidence	loss of forest or crown cover in protected areas	High threat
Commercial unsustainable rates of wood (legal) extraction		% of crown cover in production forests	High threat
Over hunting and collecting	Extent	Areas with animal populations strongly declining	High threat
Poor legal commercial harvesting practices		Data from Commercial Concessions	High threat
Conversion of forest through small-scale agriculture	Extent	Areas and locations of annual conversion	Medium threat
Direct impacts of road construction	Extent	Areas of forest conversion along new roads	Medium threat
Expansion of hydropower dams	Extent	% of major rivers obstructed	Low threat
Recent extreme droughts	Extent Time	Areas effected by extreme droughts Length of period in between droughts	Medium threat
Unsustainable firewood extraction	Extent	Areas of forest destruction caused by over-harvest	Low threat

Appendix 1 C: Conservation management indicators.

Target	Indicator
Protected area representation	% of peat swamp forest in protected areas
	% of lowland rainforest in protected areas
	% of upland rainforest in protected areas
	% of montane forest in protected areas
	% of heath forest in protected areas
	% of orang-utans in protected areas
Protected area intactness	% of intact natural habitats in protected areas
% of remaining forest in concessions	% of production forest that remains forest
Enforcement of existing legislation	Peat Conversion
Proposed protected areas	km^2 of proposed protected areas by habitat
Protected area effectiveness	RAPPAM score
Regeneration in protected areas	Regeneration Post HoB
Regeneration in protected areas	Regeneration Post HoB

Appendices 2 and 3

Appendix 2 – Conceptual Threat Model



Appendix 3 – Summary Threat Ranking Table

THREATS	Peat swamp ecosystems	Lowland forest ecosystem	Upland forest ecosystem	Montane forest ecosystem	Heath forest ecosystem	Limestone ecosystems	River ecosystems	Endangered plant species	Bornean clouded leopard	Sumatran rhinoceros	Forest edge herbivores	Large nrs. of bearded pigs	Orang-utans	Summary threat rating
	TARGETS													
Industrial conversion of natural forests	M V V High	H V V Very high	L V V Medium	L V V Medium	M V V High		L H H Low	L V V Medium	H V V Very high	L V V Medium	L V V Medium	M H V High	H V V Very high	Very high
Forest fires	H V V Very high	H H H High	M M M Medium		M V V High	L V V Medium	M M M Medium		M V H Medium			M M L Low	M H V High	Very high
Mining		L V V Medium	L V V Medium		L V V Medium	M V V High	M M M Medium	L V V Medium						High
Illegal logging	H H H High	H H M High	H M L Low		M V V High	L V V Medium			M H H Medium		L H M Low	M H M Medium		High
Over-hunting and collecting	L L L Low	L H M Low	L H M Low		L H H Low	L H V Medium	L H M Low	L V H Low	M H M Medium	H V V Very high	L H H Low	M H L Low	H H H High	High
Poor legal commercial harvesting practices	L H H Low	M H M Medium	H H H High	L H V Medium	L V V Medium		M H M Medium		M V M Medium			H L L Low		High
Commercial unsustainable rates of extraction	H M H Medium	V H H High	H H H High	M H H Medium	L V H Low		M H M Medium		M H M Medium			H H M High		High
Recent extreme droughts	V H M High	L L L Low	H M M Medium		V M L Low	H L L Low	H H L Medium						M H M Medium	Medium
Conversion of forest through small-scale agriculture		H V H High	L V H Low	L V L Low			M M M Medium						M H H Medium	Medium
Swamp drainage	H H H High												M M H Medium	Medium
Direct impact of road construction	M H H Medium	M M M Medium	M H M Medium		L L H Low		L M M Low							Medium
Unsustainable firewood extraction		L L L Low			M V H Medium	L V H Low	L M L Low							Low
Expansion of hydropower dams		L V M Low	L V M Low				L H L Low							Low
Recent extreme floods	L H M Low	L L L Low												Low
Summary target rating	Very high	Very high	High	Medium	High	Medium	Medium	Medium	High	High	Low	High	High	Very high

M - first block: Scope - how large is the extent of the threat
H - second block: Severity - how strong does the threat affect the target
V -third block: Irreversibility - how much can the impacts of the threats be reversed

Appendix 4

Final Selected Indicators and Indicator Ratings

Target	Key Ecological Attribute	Indicator	Indicator Ratings (Bold = Current, Italics = Desired)			
			Poor	Fair	Good	Very good
Lowland forest ecosystems	Extent	% of historical extent (historical baseline = 58,900 km^2)	<15%	**15-35%**	*36-50%*	>50%
	Condition	% of historical extent un-degraded	<10%	10-20%	21-30%	>30%
	Connectivity	Connectivity between fragments (% of fragments connected– currently about 40% of the lowland fragments are connected to each other and about 70% are connected through upland forests)	<20%	20-40%	***41-60%***	>60%
Upland forest ecosystems	Extent	% of historical extent (historical baseline = 89,900 km^2)	<40%	40-60%	61-80%	***>80%***
	Condition	% of historical extent un-degraded	<20%	20-40%	40-60%	>60%
Montane forest ecosystems	Extent	% of historical extent (historical baseline = 38,500 km^2)	<40%	40-60%	61-80%	***>80%***
Peat swamp ecosystems	Extent	% of historical extent (historical baseline = 38,500 km^2)	<25%	25-50%	***51-75%***	>75%
	Canopy cover	% of historical extent un-degraded (%)	<40%	40-60%	61-80%	>80%
Limestone ecosystems	Extent	% of historical extent (historical baseline =400 km^2)	<40%	40-60%	***61-80%***	>80%
Heath forest ecosystems	Extent	% of historical extent (historical baseline =4,900 km^2)	<40%	40-60%	***61-80%***	>80%
River ecosystems	Habitat condition	% 'intact' watersheds (intact to be determined)				
	Connectivity	% of length of river with intact 100 m riparian forest buffer on both sides	<30%	30-50%	51-70%	>70%
Bornean elephant	Population size	% of historical population size (about 2,000 individuals in 1980, before large-scale conversion began) (Ambu et al, 2003)	<60%	60-80%	***81-99%***	>100% or more
	Population distribution	% of historical distribution (about 27,000 km^2 in 1920, before large-scale conversion began) ((Ambu et al, 2003)	<40%	***40-60%***	61-80%	>80%
	Connectivity	% of subpopulations that are interconnected. The subpopulations are mapped by WWF Sabah	none	<60%	***>60%***	all
	Amount of suitable habitat	% of historical habitat that is suitable	only concentrations	all remaining habitats	***all remaining suitable***	all original habitats restored
Rhinoceros	Population size	Total number of individuals (data from J. Payne)	**<50**	50-200	201-500	>500
Bornean clouded leopard	Amount of suitable habitat	km^2 of suitable habitat for viable populations (>50 individuals)	<50,000	50-150,000	***150-250,000***	>250,000
Orangutans	Population density	Average density in all remaining (2007) peat swamp forests	<0.5	**0.5-1.0**	1.0-1.5	>1.5
		Average density in all remaining (2007) lowland forest	<0.5	***0.5-1.0***	1.0-1.5	>1.5
Endemic Nepenthaceae Pitcher Plants	Extant distribution	% of historical locations still viable	<50%	50-70%	***71-90%***	>90%
Banteng	Population distribution	% of historical locations occupied	**<50%**	*50-80%*	81-99%	100% or more
Bearded pig	Periodic large concentrations	Presence of large numbers (>50 individuals) at representative sites	no large numbers present	Present occasionally	Present frequently	Large numbers are resident

Sources:

Ambu, L.N., Andua, P.M., Nathan, S., Tuuga, A., Jensen, S.M., Cox, R., Alfred, R. & Payne, J. (2003) Asian elephant action plan Sabah (Malaysia), Wildlife Department, Sabah.

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Note: This table provides the full viability criteria for each indicator, whether or not data is yet available.