



WWF

REPORT

2010

Sumatra's Forests, their Wildlife and the Climate

Windows in Time: 1985, 1990, 2000 and 2009

Sumatra's Forests, their Wildlife and the Climate Windows in Time: 1985, 1990, 2000 and 2009

A quantitative assessment of some of Sumatra's natural resources submitted as technical report by invitation to the National Forestry Council (DKN) and to the National Development Planning Agency (BAPPENAS) of Indonesia

WWF-Indonesia

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Photo on front cover: Natural forest of Bukit Tigapuluh National Park, Sumatra, Indonesia © Mast Irham / WWF-Indonesia.

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Preface

This technical report was submitted by WWF upon requests by Dewan Kehutanan Nasional (National Forestry Council, DKN - letter No. 107/DKN/HK/11/2009) and by Badan Perencanaan dan Pembangunan Nasional (National Development Planning Agency, BAPPENAS) for information on forests and forestry.

The report presents scientific data and information on:

- Loss of natural forest in Sumatra and its eight mainland provinces 1985-2009.
- Loss of carbon stock in natural forest and peat.
- Deforestation and eco-floristic diversity.
- Deforestation and mega-fauna diversity.
- Suggestions for prioritizing conservation and restoration interventions in Sumatra.

WWF Indonesia is very concerned about the findings of this report: the ongoing severe loss of natural forest and degradation of peat soil and the resulting emissions from carbon stocks, the significant depletion of eco-floristic diversity and the large reduction of the island's populations of the Sumatran Elephant, Orang Utan, Rhino and Tiger.

WWF Indonesia very much welcomes this request for information by DKN and BAPPENAS since WWF is ready to actively participate in a policy dialogue on improving the state of natural forests in Sumatra. This report provides a scientific analysis of the state of some of Sumatra's natural resources since 1985. As one of the next steps, WWF will analyze Sumatran provinces' adherence to land use plans in effect since 1985. WWF Indonesia believes that the existing rate of natural forest loss is a very important indicator of the non sustainable development currently occurring in Sumatra. This must be stopped and alternative ways need to be formulated. For this report, WWF modeled the available data and made some initial suggestions for prioritizing forest conservation interventions and the areas in need of most urgent action.

WWF Indonesia welcomes comments, inputs and criticisms to this report so it can further improve data collection and analysis.

July 2010

WWF Indonesia

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1. Executive Summary

Sumatra was once a green, tropical paradise that helped Indonesia earn the nickname “Emerald of the Equator.” No more.

The forests that harbored some of the world’s highest biodiversity have been largely replaced by two trees: oil palms and acacia. Palm oil and pulp for paper are flooding global markets from Sumatra, the world’s sixth largest island. The massive land clearing for development of their plantations and harvesting of natural forest wood is measurably contributing to climate change. The habitats of Sumatran orangutans, tigers, rhinos and elephants are heavily disturbed and have been reduced so much that the populations have declined significantly.

We decided to open windows in time and take four snapshots of Sumatra from space and from the ground between 1985 and 2009. Given the current shift of global thinking towards climate change mitigation, especially through protection of forest-carbon and peat-carbon stocks, and the market’s increasing adoption of the “High Conservation Value” (HCV) principle as a tool to protect biodiversity, environmental services, and social and cultural values, we decided to report on the past and potential future of some of these values in Sumatra.

We consider as forest exclusively natural forests as they generated and represent the country’s wealth of biodiversity, provide many of its environmental services and social values, and host its huge carbon stocks. We acknowledge that the Indonesian Ministry of Forestry considers tree plantations like the mono cultures used to produce pulp for paper also as forests.

This study found:

Loss of natural forest 1985 to 2008/9 (Chapter 6)

- **The 44 million hectare Sumatran mainland was covered with 25.3 million ha of natural forests in 1985 (58% forest cover) and 12.8 million ha in 2008/9 (29%).** Over the past 23 years, Sumatra’s forests were cleared at an average annual rate of 542,000 hectares (2.1%).
- **Eighty-one percent (10.1 million ha) of all forest lost between 1985 and 2008/9 was below 150 meters elevation.** In Sumatra, lowlands below 150 meter elevation - generally much easier to clear and plant than hills and mountains - have remained rather unprotected, been highly threatened and unfairly represented in conservation areas across Sumatra. Yet, these forests contain high carbon stores, especially those located on peat soil, represent critically endangered and endangered eco-floristic sectors and are habitat for highly threatened mega-fauna species.
- **As lowland forest on non peat soil below 150 m.s.l. became scarcer, loss of other forests became faster.** Peatland forest loss continued to increase and relatively more forest above 150 m elevation was lost between 2000 and 2008/9 (23% of total loss) than between 1990 and 2000 period (9% of total loss).
- **Average annual natural forest loss in Riau, Aceh, North Sumatra and West Sumatra increased between 2000 and 2008/9** compared to 1990 to 2000, both in terms of area size and of percentage of loss.
- **Eighty-one percent of all Sumatran forest loss between 2006/7 and 2008/9 occurred in four provinces in central Sumatra:** Riau (380,143 hectares, 35%), Jambi (199,712 hectares, 19%), South Sumatra (152,657 hectares, 14%) and West Sumatra (143,542 hectares, 13%).
- **Riau Province had Sumatra’s highest deforestation rate.** In 1985, Riau had by far the most natural forest in Sumatra (6.9 million ha, 28% of all natural forest on the island). By 2008, Riau had lost 4.4 million ha (63%) at an average annual rate of up to 4.8% to become 2nd most forested province. More than one third of Sumatra’s forest loss occurred in Riau overall, accelerating from 26% of Sumatra’s

total loss in 1985-1990 to 48% in 2000-2008/9. Plantations increasingly have been replacing much of that forest: Riau produces more palm oil and more pulp for paper than any other province in Indonesia.

Loss of carbon stock in natural forest and peat (Chapter 7)

- **Sumatra's 12.8 million ha of 2008/9 natural forests are estimated to contain 2.1 gigatons of carbon applying IPCC default values.** Most of these forests have been logged one or more times and therefore will sequester large amounts of carbon as they re-grow.
- **Sumatra's 7.2 million ha of peatlands were estimated to store 18.8 gigatons of carbon in 2002.** Sumatra has 40% of Indonesia's (46.6 gigatons), 37% of Southeast Asia's (50.4 gigatons), 36% of the world's tropical (52.2 gigatons) and 4-9% of all global peatland carbon stores (202-500 gigatons). This study mapped 1.7 million ha of additional peat areas not included in the above estimates, suggesting that Sumatra's peat carbon storage is likely to be even bigger than previously assumed.
- **By far the most of Sumatra's 21 gigatons of forest and peat carbon are concentrated in Riau (72% total), Jambi (7.9%) and South Sumatra (7.6%).**
- **The loss of 12.5 million ha Sumatran forest since 1985 may have caused 7.5 gigatons of CO₂ emissions, not including closely associated emissions from peat degradation. These emissions were equivalent to 20% of the IPCC estimate for global annual average CO₂ emissions associated with land-use change** (primarily deforestation but without peat emissions) in the 1990s.
- **In addition to the emissions from forest loss, the Indonesian Ministry of Forestry estimated that every year 1.1 gigatons of CO₂ were emitted because of clearing, draining and burning of Sumatra's peatlands between 1990 and 2002.** Today, a similar magnitude of CO₂ emissions is expected. Scientists expect an average 4.4 m deep peat to survive no more than 2 oil palm and 5 pulpwood plantation rotations before it collapses and all carbon stocks have been set free. We expect that a very significant portion of the 2.5 million hectare of Sumatra's still forested peatlands is also being drained and emitting CO₂ through decomposition, though at slower speed than under plantations.
- **The Indonesian Ministry of Forestry estimated that Sumatra's total annual CO₂ emissions from loss of natural forest and peat decomposition and burning were 1.2 gigatons per year,** contributing significantly to global climate change. Sumatra's emissions exceed the combined total of all annual emission reductions pledged under the Kyoto protocol (0.93 gigatons).
- **Riau may have contributed to around 60% to Sumatra's total emissions from natural forest loss and peat drainage.**
- **Much of the emissions are due to Sumatra's "Mega Pulp Project" steadily expanding in the peat lands of Riau, Jambi, North, West and South Sumatra since the 2000s. Already totaling 2.2 million ha today, built on much deeper peat, with faster drainage and continuously expanding, Sumatra's "Mega Pulp Project" is a climate disaster in its making, far worse than Central Kalimantan's infamous ex Mega Rice Project.** Riau is absolute leader in Sumatra's "Mega Pulp Project", having allowed the conversion of 71% of the total area, having already developed 37% of all concession areas in Sumatra and threatening almost all of the natural peat forest still standing in all pulpwood plantation concessions. REDD could stop this.
- **The continuing loss of natural forests and degradation and burning of Sumatra's peat directly counter Indonesian and global efforts to reduce industrial greenhouse gas emissions.** The simplest and most effective measures to prevent further peat emissions are conservation of remaining peatland forests and rehabilitation of degraded peatland forests and deforested soils. Considering Sumatra's huge historical and expected huge future emissions from loss of natural forest and decomposition and burning of peat soil, sealing Sumatra's forest and peat carbon stocks would make the most efficient and significant contribution to the country's commitment to reduce its emissions by 26% to 41%. For example, moving towards a "zero" emissions goal in Sumatra's 1.7 million hectare deep peat Kampar /

Kerumutan landscape alone could possibly contribute more than 50% towards Indonesia's goal of reducing 26% of its emissions.

Loss of Eco-Floristic Diversity in Sumatra (Chapter 8)

- **Natural forest cover change analysis revealed that by 2008/9, 17 out of Sumatra's 38 distinct eco-floristic sectors (EFSs) representing unique ecosystems distinguished by tree floral and environmental parameters had become 'critically endangered', 'endangered', or 'vulnerable'.** Eighty-seven percent of all natural forest loss occurred in these EFSs. Almost 40% of all natural forest in 2008/9 remained in these EFSs.
- **This study identified the EFS that face the highest extinction risks and are in the most desperate need of protection and forest restoration (Map 12).** New conservation and forest restoration areas should urgently be considered in the ongoing island, provincial and district land-use planning to mitigate threats to some of these EFSs and prevent their extinction.

Decline of Sumatra's Mega-Fauna Diversity (Chapter 9)

- **Sumatran elephants:** By 2007, the island's 1985 population is believed to have declined up to half its size, an estimated 2,400 to 2,800 individuals. Forest habitat loss has been the single biggest threat to Sumatra's elephants. Most of 23 "extinctions" of local elephant herds occurred in areas where large areas of forest had been lost or severely fragmented. Subsequent human-elephant conflict rather than poaching became the top cause of death. Riau's population, faced by the island's most severe forest loss, was decimated from >1300 to <200 individuals.
- **Sumatran orangutans:** By 2007, the island's population of the 1990s had been reduced by at least 50%, an estimated 6000 to 7000 individuals. Development of oil palm plantations and agriculture, slash-and-burn farming, roads, illegal and legal logging, and transmigration development continue to destroy, disturb and fragment orangutan habitat, leading to human-orangutan conflicts with retaliatory killings and captures of young for the illegal pet trade. Even the world's only successful reintroduced Sumatran orangutan population, in Jambi Province, is in peril. The pulp & paper companies are clearing their natural forests to produce paper for the global market.
- **Sumatran rhinoceros:** Since 1986, the Sumatran population of the critically endangered Sumatran rhinoceros is estimated to have declined by up to 82% to possibly as few as 145 individuals. After initial huge losses to poaching, habitat loss from logging, mining, shifting agriculture and other new land uses now appears to have become the main threat to the survival of Sumatran rhino.
- **Sumatran tigers:** The breeding population of the critically endangered Sumatran tiger was estimated to be fewer than 250 mature individuals. The population has been declining due to habitat loss, human-tiger conflict and retaliatory killings, and poaching. Sumatra has only very few areas left where the Sumatran tiger coexists with the Sumatran elephant, orangutan and rhino. They need to be given highest priority for conservation.

Prioritizing conservation interventions in Sumatra (Chapter 10)

- **The majority of Sumatra's remaining natural forest contains more than just forest-carbon as a conservation value.** 93% of Sumatra's forest areas overlap either with very carbon rich peatlands, with "critically endangered" or "endangered" EFSs, and/or with distribution ranges of at least one of the four flagship species studied. Fifteen percent of Sumatra's remaining natural forest in 2008/9, 1.9 million hectares, had all these carbon and conservation values present.
- **Half of Sumatra's already-deforested areas contain important conservation values which require immediate restoration,** especially heavily drained peatlands and tiger ranges.

Prioritizing development areas in Sumatra (Chapter 11)

- Sumatra's mainland had 4.5 million hectares of potential "wastelands" in 2008/9, 72% of which were outside peatlands (3.2 million ha). They were concentrated in South Sumatra (35% total), Aceh (19%), North Sumatra (13%) and Lampung (12%).

2. Introduction

Sumatra was once a green, tropical paradise that helped Indonesia earn the nickname “Emerald of the Equator.” No more.

The forests that harbored some of the world’s highest biodiversity have been largely replaced by two trees: oil palms and acacia. Palm oil and pulp for paper are flooding global markets from Sumatra, the world’s sixth largest island. The massive land clearing for development of their plantations and harvesting of natural forest wood is measurably contributing to climate change. The habitats of Sumatran orangutans, tigers, rhinos and elephants are heavily disturbed and have been reduced so much that the populations have declined significantly.

We decided to open windows in time and take snapshots of Sumatra from space and from the ground between 1985 and 2009. Given the current shift of global thinking towards climate change mitigation, especially through protection of forest-carbon and peat-carbon stocks, and the market’s increasing adoption of the “High Conservation Value” (HCV) principle¹ as a tool to protect biodiversity, environmental services, and social and cultural values, we decided to report on the past and potential future of some of these values in Sumatra.

We looked at: which forests were lost when and where (Chapter 6)? How has the deforestation affected our climate (Chapter 7)? What happened to the island’s globally unique floral (Chapter 8) and faunal (Chapter 9) diversity that includes some of the world’s most charismatic wildlife species? Which are the forests that absolutely need to be conserved, which are the areas that need to be restored (Chapter 10)? Where should development continue without converting natural forest and peat (Chapter 11)?

Sumatra has already lost much of its natural forest, but there are signs that some government decision-makers are taking note.

In March 2008, Government of Indonesia Regulation No. 26 Year 2008² on national spatial planning was published with a draft National Land Use Plan. The draft plan proposed that 91 percent of all natural forest remaining on Sumatra as of 2008/9 to be protected either as Conservation Area or Protection Forest.

In October 2008, all 10 Sumatran governors, supported by the Indonesian Ministries of Interior, Forestry, Environment and Public Works, announced their joint commitment to “save and conserve the ecosystem of Sumatra Island in order to balance ecological functions and economic development for the people of Sumatra, by (1) initiating ecosystem-based land-use planning, (2) restoring critical areas to protect ecosystem services, and (3) protecting areas with high conservation value to protect ecosystem services, biodiversity, and the global climate.”^{3, 4}

President of Indonesia commits to reduce the country’s emissions by 26 – 41 % of the business-as-usual assumption of 2.9Gt CO₂ in 2020.

But are these developments serious? Will they achieve what they promise? Will they come in time to save Sumatra?

At the time of final editing of this report, May 2010, the Government of Indonesia was finalizing the new island-wide land-use plan for Sumatra to be put into law as a presidential decree. The island’s provinces and their districts will have to “harmonize” their respective land-use plans with the national plan by 2011, a process that is already ongoing in many districts and several provinces. World’s governments are discussing a post-2012 climate change framework including a REDD mechanism, which will generate a powerful global market for carbon as a new commodity able to compete successfully with the commodities that have been driving Sumatra’s forest loss: palm oil and pulp for paper.

We prepared this study to provide a quantitative basis for policy dialogue and decision making by Sumatra’s stakeholders, its people, its corporate producers and their buyers and investors, its academia, and its

regulators, Government agencies at local, provincial and national levels. We hope that business-as-usual will be avoided and stakeholders will decide to protect the values of Sumatra's natural resources and fully implement the Sumatran governors' 2008 commitment. Sumatra provides many opportunities to reach Indonesia's published target of reducing emissions.

We hope this report can be used to identify sites and actions where significant emission reductions can be achieved in short time.

3. Acknowledgements

Over the past several years, WWF-Indonesia has compiled a comprehensive Geographical Information System on Sumatra. We would like to thank the many friends and colleagues, foundations, companies and government offices who helped compile these data from many different sources. Land-use plans and concession maps are from government agencies at national, provincial and local levels and from companies. Species-related information is from many of the scientists, NGOs^a, foundations and government agencies who track this information in the many regions of Sumatra. Wetlands International produced part of the peat range map we referred to in some of our analysis. Some of our natural forest coverage analysis referred to data provided by the Forest Inventory Monitoring Project, KKI Warsi, Martin Hardiono, the South Sumatra Forest Fire Management Project, and the World Conservation Society.

We are grateful to Ajay Desai (co-chair, IUCN Species Survival Commission Asian Elephant Specialist Group), Christy Williams (WWF International), Florian Siegert (University of Munich, GeoBio-Center), Hariadi Kartodihardjo (Institut Pertanian Bogor), Hariyo T. Wibisono (Wildlife Conservation Society-Indonesia Program), Ian Singleton (Sumatran Orangutan Conservation Programme, PanEco-YEL), John Payne (WWF-Malaysia), Kerry Crosbie (Project Director, Asian Rhino Project), Kristin Nowell (Red List coordinator, IUCN Species Survival Commission Cat Specialist Group), Matthew Linkie (Fauna & Flora International), Peter Pratje (Frankfurt Zoological Society), Simon Hedges (co-chair, IUCN Species Survival Commission Asian Elephant Specialist Group), Sri Suci Utami Atmoko (Universitas Nasional) and Susie Elis (executive director, International Rhino Foundation) for reviewing parts of this report that relate to their respective areas of expertise, and we are especially grateful to our colleagues Chairul Saleh, Adhi Hariyadi and Jan Vertefeuille for their reviews and edits. Any remaining inaccuracies are not the reviewers' fault. So many data were processed for this report and so many contradictions exist between different sources of data that in the end we, the authors, had to make the final decision on which data to use and are the ones responsible for this product.

We are very appreciative of the Indonesia's National Forestry Council invitation to WWF and other NGOs to provide data and information on the condition of Indonesia's forests and hope this report will support the council's work.

Finally, we would like to thank the donors who made this report and much of its data collection possible: the Critical Ecosystems Partnership Fund, WWF-US, WWF-Japan, WWF-UK, WWF-Germany, WWF-Austria and WWF International.

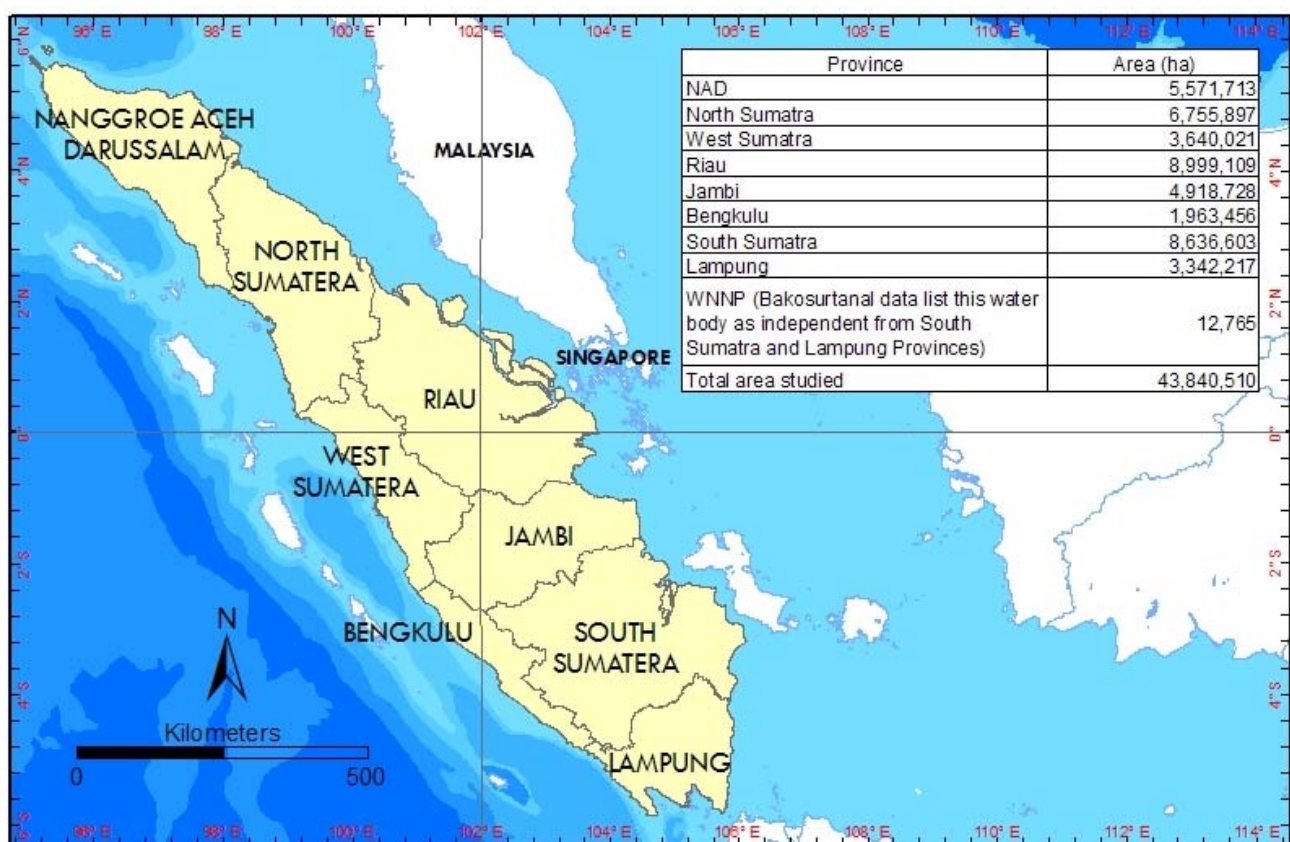
^a Over 20 NGOs working on Sumatran issues began coordinating their efforts through FORTRUST (Forum Tata Ruang Sumatera) in 2008 and have pledged to support Government's land use planning efforts for the island.

4. Study Area

Our analysis focused on the approximately 44 million-hectare mainland of Sumatra (yellow area in Map 1).

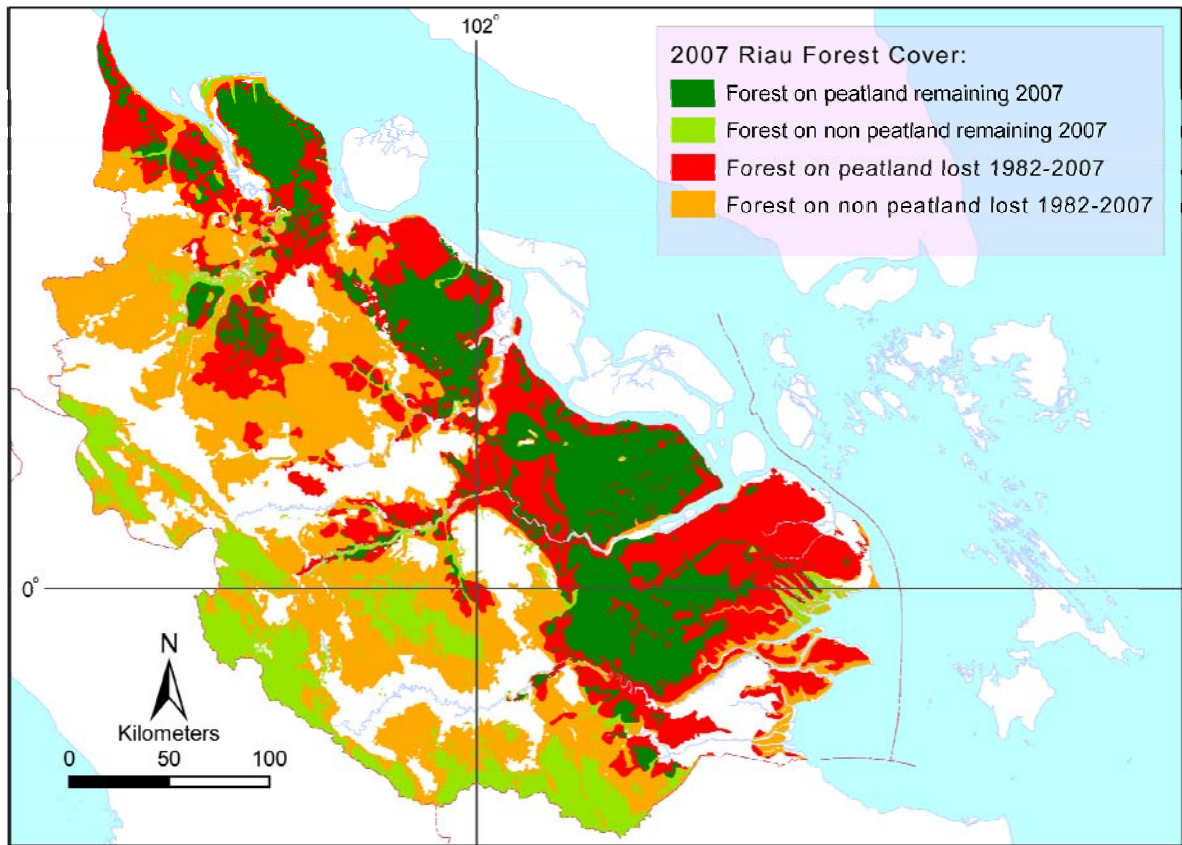
Sumatra is the world's sixth-largest island and the second-largest in the Malay Archipelago after Borneo. It is surrounded by a series of smaller islands which we did not include in this study. Located across the Straits of Malacca south of Singapore and Peninsular Malaysia, it is the western-most extension of the Indonesian archipelago. Together with Borneo and Java it forms Sundaland.

The 44 million-hectare island is crossed by the equator, is about 1800 kilometers long and 450 kilometers wide, and has two major geographical regions. The Barisan mountain ridge, with an average altitude between 2,000 and 2,500 meters and with many emerging volcanoes of up to 3,800 meters, runs along the island's Indian Ocean coastline in the west, vast flatlands and peat swamps extend from there towards the Malacca Straits in the east.

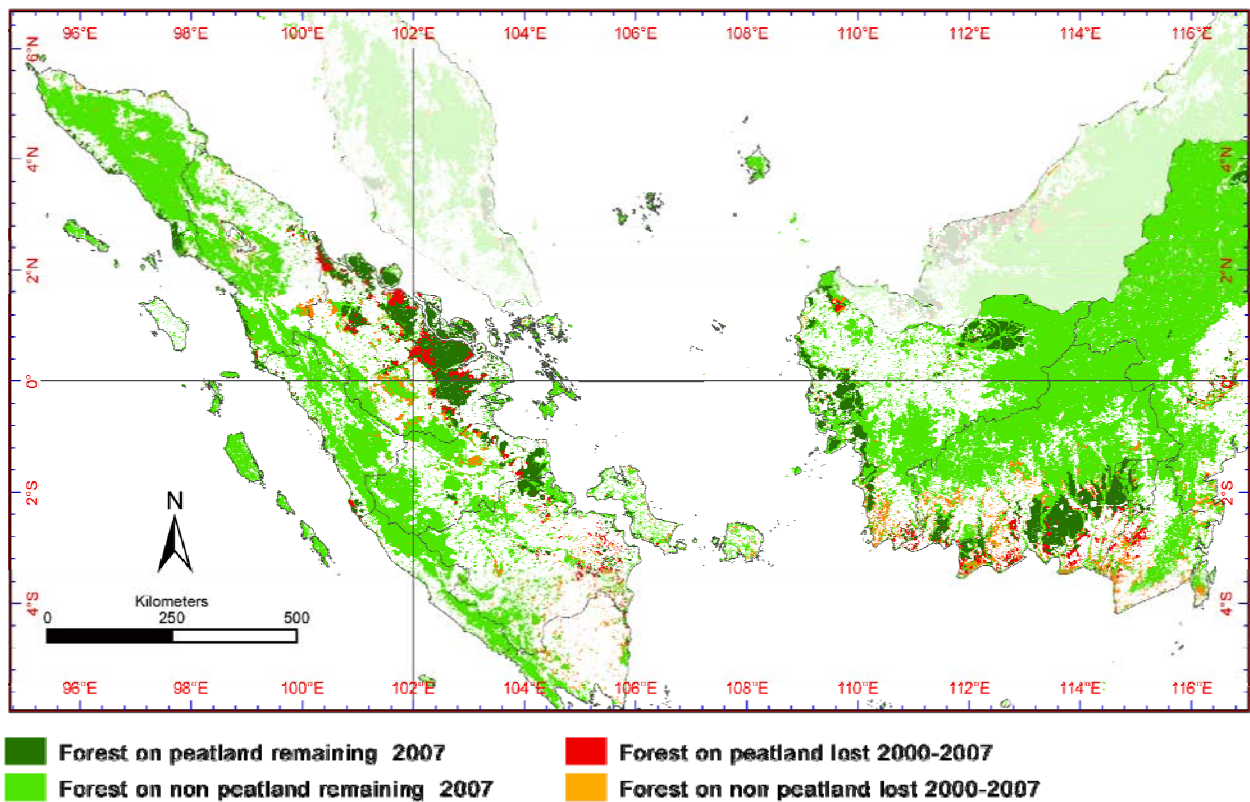


Map 1.—Sumatra mainland's eight provinces (Government of Indonesia, Bakosurtanal, 2008).

Sumatra recently received worldwide attention when it was revealed that its central province of Riau has had the world's highest rate of natural forest loss, generating huge CO₂ emissions from loss of above-ground biomass and degradation and burning of deep peat soils (Map 2)^{5, 6, 7}. Sumatra lost larger areas of forest between 2000 and 2007 than its neighbor Borneo, and a lot of them were on carbon-rich peat lands (Map 3).



Map 2.—Natural forest loss in Riau on peat (red) and non peat soil (orange) between 2000 and 2007, and forest remaining on peat (dark green) and non peat (light green) in 2007.



Map 3.—Deforestation in Sumatra and Kalimantan on peat (red) and non peat soil (orange) between 2000 and 2007 and forest remaining on peat (dark green) and non peat (light green). Map was provided by SarVision, using MODIS/SPOT Vegetation satellite images with a 250-1000 m resolution.

5. Data Collected, Generated, Analyzed and Interpreted

We used the following baseline data in our Sumatra Geographical Information System for this report:

Data set 1. Natural forest cover of Sumatra's 38 eco-floristic sectors between 1985 and 2008/9 - Yves Laumonier and Setiabudi defined and delineated Sumatra's eco-floristic sectors in the 1980s⁸ based on 10 years of extensive field surveys throughout the island. For this report, we calculated the natural forest cover remaining in each sector in 1985, 1990, 2000, 2006/7 and 2008/9 using their original "Sumatra Vegetation Map 1985,"^{9, 10, 11} various forest cover data provided by groups working in Sumatra and corrected by us, or generated by us based on Landsat images (check Appendix 1 for methodology).

Natural forest delineated for this study was defined as original natural (as opposed to anthropogenic) vegetation dominated by trees with a crown cover of more than 10%. We consider as "forest" exclusively natural forests as they generated and represent the country's wealth of biodiversity, provide many of its environmental services and social values, and host its huge carbon stocks. We acknowledge that the Indonesian Ministry of Forestry considers tree plantations like the mono cultures used to produce pulp for paper also as forests.

Data set 2. Distribution of peat soil and four flagship species - We digitized maps provided by the authors listed below and used them "as is" without modification by us for this analysis.

- **Sumatran peat lands** mapped by Wetlands International¹² and peat related eco-floristic sectors mapped by Laumonier¹³.
- **Sumatran elephant distribution** 1985 and 2008 mapped by Blouch & Symbolon (1985)¹⁴, Departemen Kehutanan (2007)¹⁵ and Tim Relokasi Dinas Kehutanan Propinsi Lampung *et al.* (2008)¹⁶.
- **Sumatran orangutan distribution** 1992, 2001/2002 and 2007 mapped by Rijksen & Meijaard (1999)¹⁷, Singleton *et al.* (2004)¹⁸ and Wich *et al.* (2008)¹⁹.
- **Sumatran tiger distribution** 1996/2005 modeled by Wikramanayake *et al.* (1998, labeled Tiger Conservation Units)²⁰ and revised by Sanderson *et al.* (2006, labeled Tiger Conservation Landscapes)²¹.
- **Sumatran rhino distribution** between 1790 and 1973 mapped by van Strien (1974)²², 1990 mapped by Santiapillai & MacKinnon (1991)²³ and 2007 mapped by Indonesian Ministry of Forestry (2007)²⁴.

Data set 3. Official land use - We digitized maps provided by the authors below and used them "as is" without modification by us for this analysis.

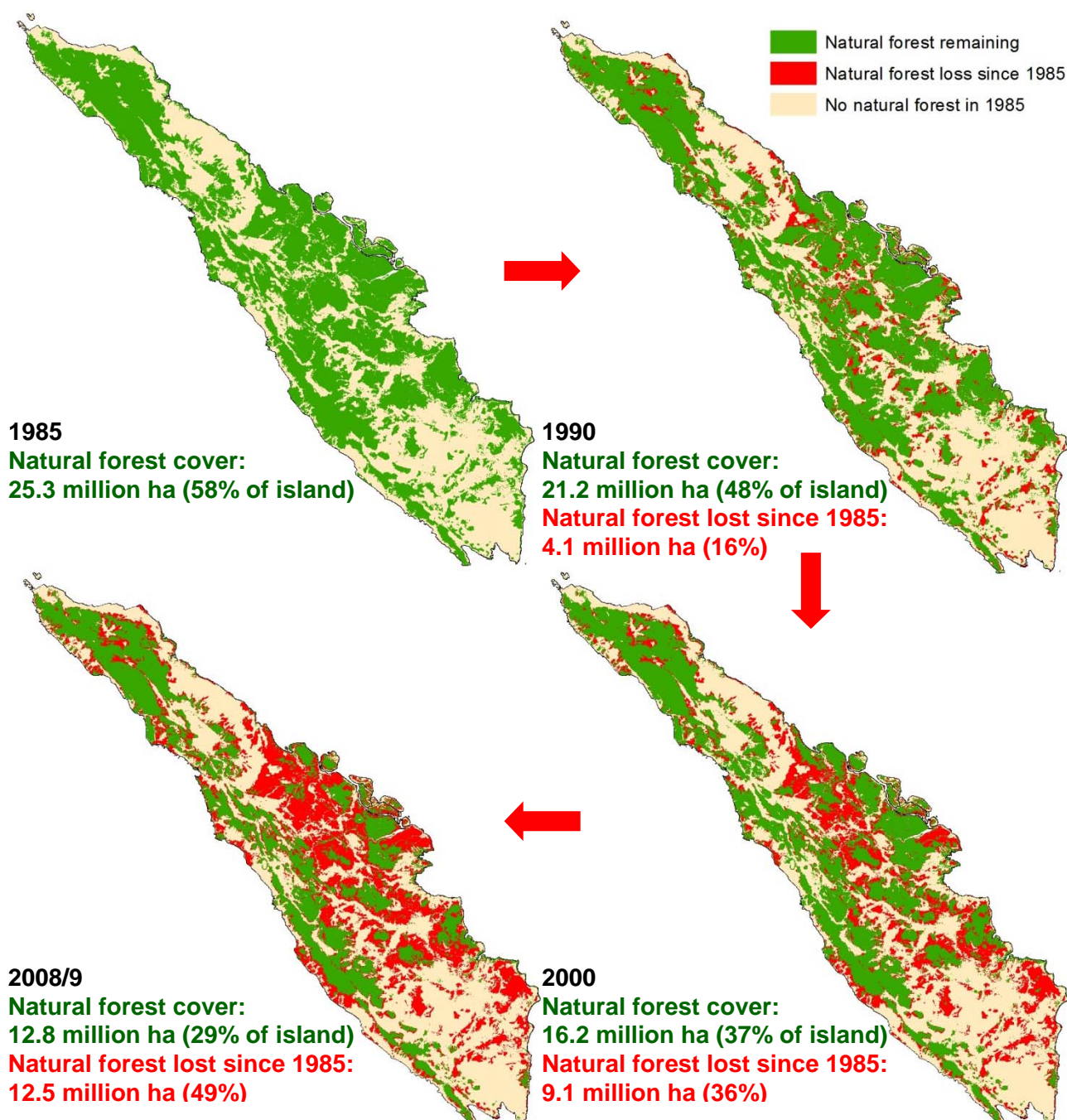
- **Indonesian Consensus Forest Land Use Plan 1985 (Tata Guna Hutan Kesepakatan, TGHK)** by Indonesian Ministry of Forestry (1986)
- **Padu Serasi** for all provinces except Riau by Badan Koordinasi Tataruang Nasional.
- **Tesso Nilo National Park**; the above National Land Use Plan did not include the recently declared Tesso Nilo National Park; therefore we added this to our analysis.
- **HTI Concessions** by Riau Forestry Service (2006) & Ministry of Forestry (2005).

Data set 4. Basic data - We digitized maps provided by the authors below and used them "as is" without modification by us for this analysis.

- Sumatra's **provincial boundaries** from the Government of Indonesia's Bakosurtanal (2008).
- **Island coastline** from Government of Indonesia's Baplan (2006).
- **Elevation** data from Jarvis, A., H.I. Reuter, A. Nelson, E. Guevara (2008) Hole-filled SRTM for the globe Version 4, available from the CGIAR-CSI SRTM 90m Database: <http://srtm.csi.cgiar.org>

6. Loss of Natural Forest 1985 to 2008/9

Twenty-five million hectares of natural forest covered Sumatra in 1985, spreading across 58% of the main island (Map 4a). By 2008/9, 23 years later^b, half of the forest (12.5 million hectares) had been cleared at an average speed of 542,000 hectares per year, with an annual deforestation rate of 2.1% (Map 4 a to d). Contrary to the global image of Sumatra as a “green” island covered by tropical rain forest, only 29% (12.8 million hectares) was still covered by natural forest in 2008/9. The average area of forest lost each year in the periods 1985 – 1990, 1990 – 2000 and 2000 – 2008/9 declined from 810,888 ha to 503,983 ha and 421,290 ha as available forest cover shrank. The rate of deforestation remained steady at 2.4% in 1990 – 2000 and 2.6% in 2000 – 2008/9.



Map 4 a to d.—Natural forest in Sumatra in 1985, 1990, 2000 and 2008/9 (green) and lost since 1985 (red).

^b Sumatra’s 2008/2009 natural forest cover is based on an interpretation of Landsat images taken in 2008 and 2009, the earliest date was 8 May 2008, the latest 30 July 2009, average date was 31 October 2008. We decided to calculate average annual deforestation rates for 23 years between 1985 and 2008 (see Appendix 1).

Natural forest loss by elevation and soil type

We compared natural forest loss in four soil type and elevation categories: less than 150 meters elevation (1) on peat and (2) on non peat, (3) 150-300 meters elevation and (4) greater than 300 meters elevation. 150 and 300 meters elevation were considered important altitudinal boundaries between distinct ecological zones by Laumonier²⁵. Natural forest on peat soil above 150 meters elevation was negligible (3,785 ha in 1985), we therefore did not further analyze this category. Elevation estimates were based on SRTM 90 meter models and peat soils were based on Wetlands International data.

In Sumatra, lowlands below 150 meter elevation - generally much easier to clear and plant than hills and mountains - have remained rather unprotected, been highly threatened and unfairly represented in conservation areas across Sumatra. In 1985, 57% of Sumatra's natural peatland and non peatland forest occurred at <150m but only 9 and 10%, respectively were protected as Conservation or Protection Forest zones by the Indonesian Consensus Forest Land Use Plan (Tata Guna Hutan Kesepakatan, TGHK) (Table 1 top). By 2008/9, 81% (10.1 million ha) of all natural forest loss in Sumatra had occurred below 150m (Table 1 bottom, red and orange areas in Map 5).

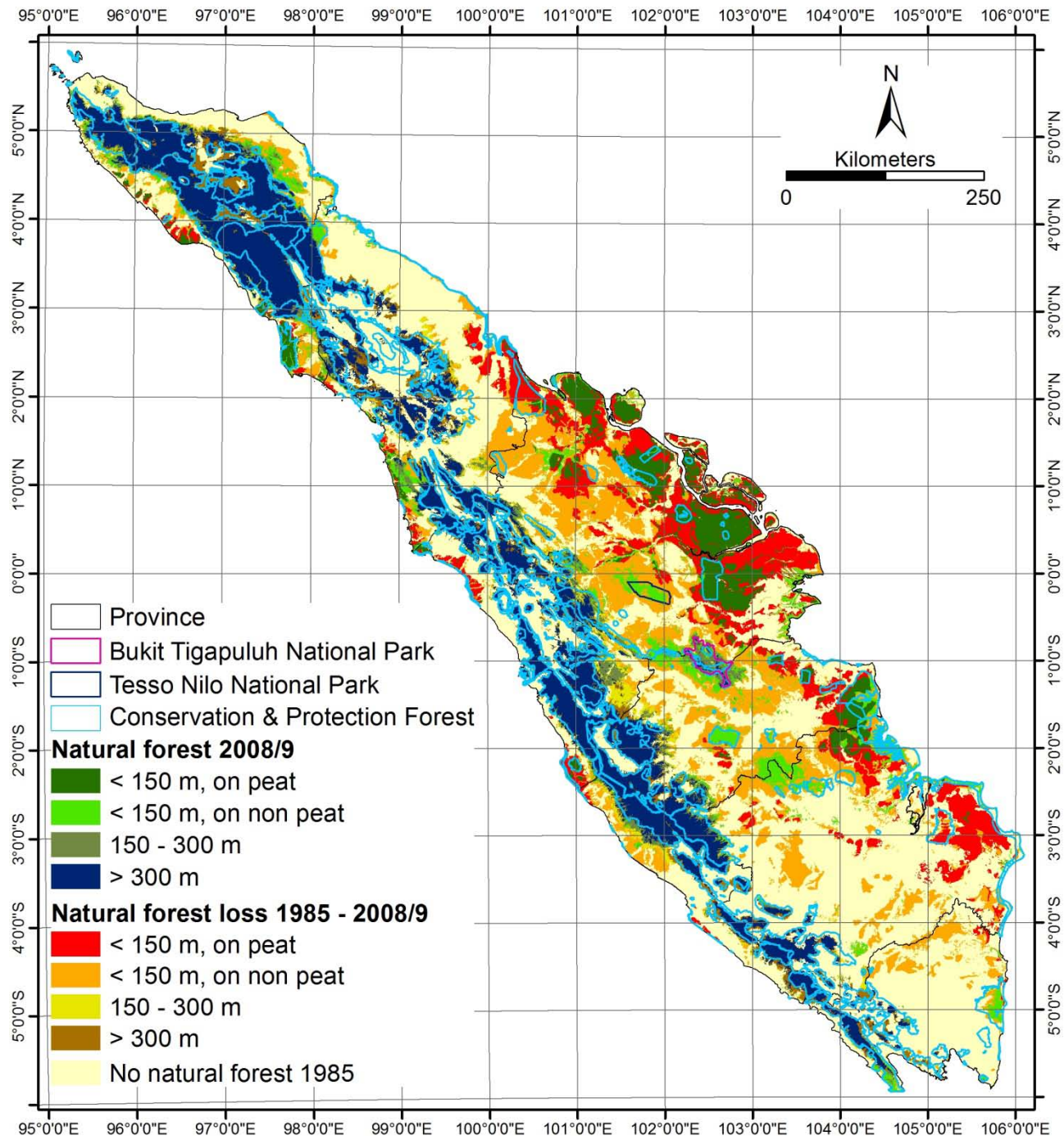
Despite their very high vulnerability to clearance, these very low lying forests remain proportionally under protected through Conservation or Protection Forest zones by the TGHK in Riau and the RTRWP–Padu Serasi in Sumatra's other provinces (Table 1 top, light blue boundary in Map 5). Yet, these forests contain high carbon stores, especially those located on peat soil (Chapter 7), represent critically endangered and endangered eco-floristic sectors (Chapter 8) and are habitat for highly threatened mega-fauna species (Chapter 9).

Table 1.—(top) *Natural forest remaining in 1985 and 2008/9 by altitude and soil category, % of forest that is protected in each category and % of all protected forest protected that lies within each category and (bottom) natural forest loss by category during 1985 – 1990, 1990 – 2000, 2000 – 2008/9 and 1985 – 2008/9, and percentage of 1985 forest loss in each category and contribution of each category's forest loss to overall Sumatra forest loss.*

Category		Natural forest in 1985			Natural forest in 2008/9		
		Area (ha)	% of category protected	% of all protected forest	Area (ha)	% of category protected	% of all protected forest
< 150 m, on peat	Total	5,825,129			2,172,248		
	Protected	520,963	9%	7%	468,335	22%	6%
< 150 m, on non peat	Total	8,494,550			1,998,869		
	Protected	809,219	10%	10%	577,890	29%	8%
150 - 300 m	Total	1,907,197			1,214,149		
	Protected	508,835	27%	6%	457,174	38%	6%
> 300 m	Total	9,046,774			7,424,591		
	Protected	6,103,892	67%	77%	5,934,811	80%	80%
NI	Total	1,936			1,139		
	Protected	223	12%	0%	441	39%	0%
All Sumatra	Total	25,275,586			12,810,997		
	Protected	7,943,131	31%	100%	7,438,651	58%	100%

Category	Natural forest loss					
	1985-1990	1990-2000	2000-2008/9	1985-2008/9		
	Area (ha)	Area (ha)	Area (ha)	Area (ha)	% 1985 forest lost in category	% of overall Sumatra 1985 forest loss
<150 m, on peat	679,866	1,695,411	1,277,602	3,652,880	63%	29%
<150 m, on non peat	2,290,384	2,889,057	1,316,240	6,495,681	76%	52%
150-300 m	291,382	175,017	226,649	693,048	36%	6%
> 300 m	792,311	280,240	549,632	1,622,182	18%	13%
Total	4,053,943	5,039,725	3,370,124	12,463,792	49%	100%

Sumatra's peatland forest (dark green areas in Map 5) remains mainly along the eastern coast of Sumatra, mostly in Riau, 78% are not protected by land use plans. Forest on mineral soil below 150m (light green areas in Map 5) remains in small fragmented blocks throughout the island, 71% are not protected. Tesso Nilo (dark blue boundary in Map 5) and Bukit Tigapuluh (pink boundary in Map 5) national parks were recently created to save two of Sumatra's remaining dry lowland forest blocks. But large areas of low lying forest were excluded from the original proposals after heavy industry lobbying and today remain highly threatened with conversion.



Map 5.—Natural forest loss 1985 to 2008 by soil and elevation. Peatland forest (dark green, close to 100% are below 150 meter above sea level) and non-peatland forest <150 meters, 150–300 meters and >300 meters above sea level remaining in 2008 and lost since 1985.

The majority (78%) of Sumatra's forests protected by TGHK in Riau and RTRWP-Padu Serasi for all other provinces are located mainly in hill or montane areas above 300 meter elevation, despite the fact that they are more difficult to develop and therefore less threatened (Map 5). By 2008, this category lost 18% of its 1985

forest, as compared to around 70% of loss in the <150m categories (Table 1 bottom).

Average annual loss of forest on non peat soil <150m became less and less through the three periods (orange), although the rate of loss increased between the 1990-2000 and 2000-2008 periods (Figure 1). As this forest type became scarcer, the loss of other forest types became faster. The rate of peatland forest loss (red) continued to increase and the loss of forest >150m elevation (brown and khaki) increased significantly in 2000-2008/9 (23% of the total loss) compared to 1990-2000 period (9% of the total loss).

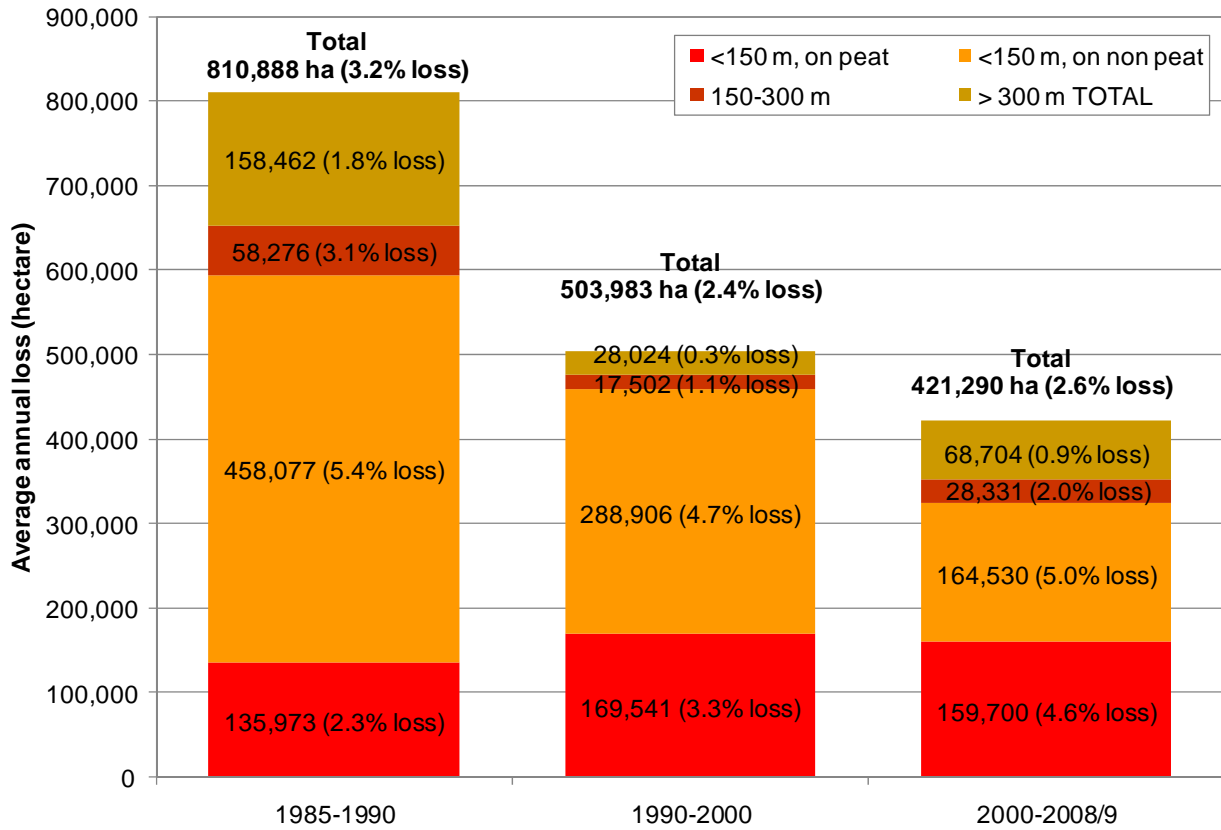


Figure 1.—Average annual natural forest loss in Sumatra 1985-1990, 1990-2000 and 2000-2008/9 at <150m (on peat or non peat), 150-300 m and >300m elevation in hectares and percentage.

Natural forest loss by province

Sumatra's mainland provinces differed in the total area of natural forest they lost and in the speed with which they lost their forests (Figure 2, Table 2).

In 1985, Riau Province had by far the most natural forest (6.9 million ha): 28% of all natural forest in Sumatra (Figure 2). The 2nd most forested province was Aceh with 4.2 million ha (17%) and 3rd was South Sumatra with 3.4 million ha (13.6%). By 2008/9, Riau had lost 63% (4.4 million ha) of its natural forest, though it is still the 2nd most forested province (20% of all forest in Sumatra with 2.6 million ha). South Sumatra lost the 2nd largest amount of forest (2.4 million ha) and became 3rd least forested province. Aceh lost the smallest portion of its 1985 forest (23%, 0.9 million ha) among all provinces and became the most forested province of Sumatra.

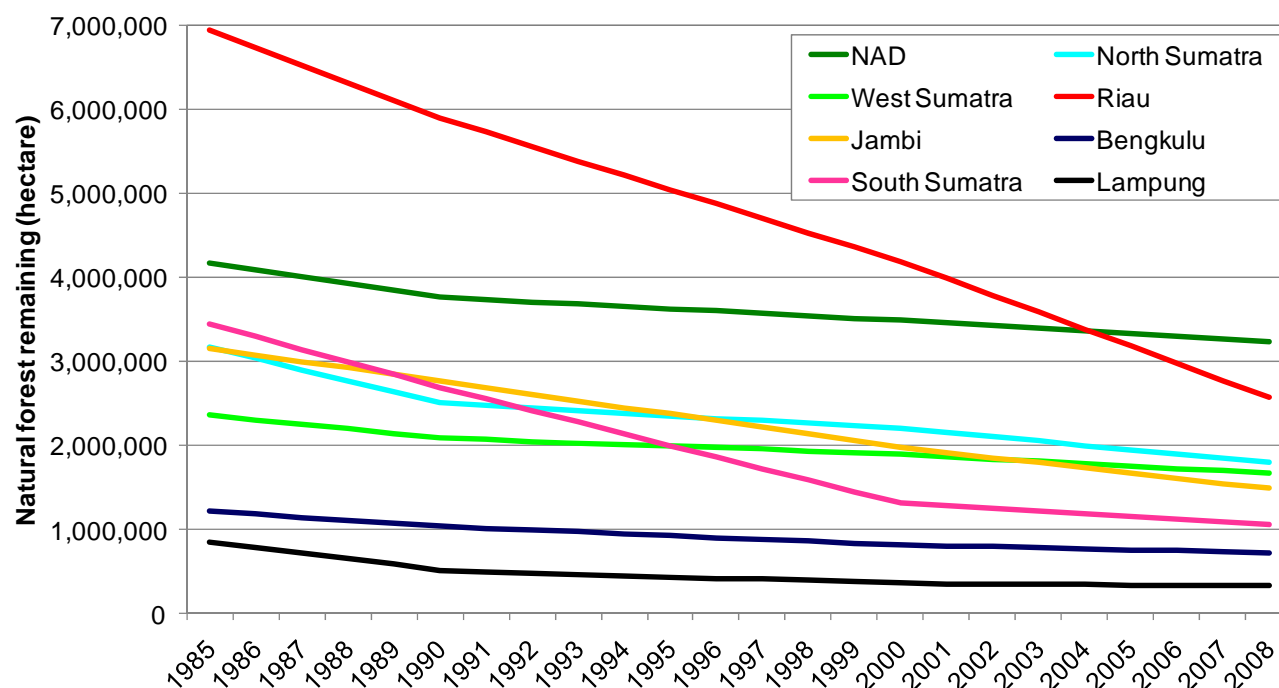


Figure 2.—Natural forest loss in Sumatra's mainland provinces from 1985 to 2008/9.

Over our 23 year study period, Riau lost more than one third (35%, 4.4 million ha) of all the natural forest that was lost in Sumatra (Table 2, Figure 3, Map 6). Riau consistently outpaced all other provinces, losing more forest in each of the three periods we compared: 1985–1990 (26%, 1.0 million ha), 1990–2000 (34%, 1.7 million ha) and 2000–2008/9 (48%, 1.6 million ha).

Table 2.—Natural forest loss over three study periods. Provinces are ranked by 1985 – 2008/9 loss.

Province	1985-1990			1990-2000			2000-2008/9			1985-2008/9		
	(ha)	% 1985	% Total Loss	(ha)	% 1990	% Total Loss	(ha)	% 2000	% Total Loss	(ha)	% 1985	% Total Loss
Riau	1,049,112	15.1%	25.9%	1,710,961	29.0%	33.9%	1,618,982	38.7%	48.0%	4,379,055	63.0%	35.1%
South Sumatra	756,630	22.0%	18.7%	1,382,860	51.5%	27.4%	247,421	19.0%	7.3%	2,386,910	69.3%	19.1%
Jambi	382,910	12.2%	9.4%	796,560	28.8%	15.8%	487,954	24.8%	14.5%	1,667,423	53.0%	13.4%
North Sumatra	666,070	21.1%	16.4%	300,333	12.0%	6.0%	407,551	18.5%	12.1%	1,373,954	43.4%	11.0%
NAD	407,641	9.8%	10.1%	277,169	7.4%	5.5%	260,500	7.5%	7.7%	945,311	22.7%	7.6%
West Sumatra	273,778	11.6%	6.8%	190,019	9.1%	3.8%	228,488	12.1%	6.8%	692,286	29.4%	5.6%
Lampung	342,139	40.4%	8.4%	156,177	30.9%	3.1%	32,226	9.2%	1.0%	530,542	62.6%	4.3%
Bengkulu	176,161	14.6%	4.3%	225,749	21.9%	4.5%	87,197	10.8%	2.6%	489,107	40.5%	3.9%
TOTAL	4,054,442	16.0%	100.0%	5,039,828	23.7%	100.0%	3,370,319	20.8%	100.0%	12,464,589	49.3%	100.0%

Riau's average annual loss during the three study periods remained higher than other provinces and increased both in terms of size and rate from the 1990-2000 to the 2000-2008/9 period (Figure 3). Aceh, North Sumatra and West Sumatra also increased forest loss between these two periods.

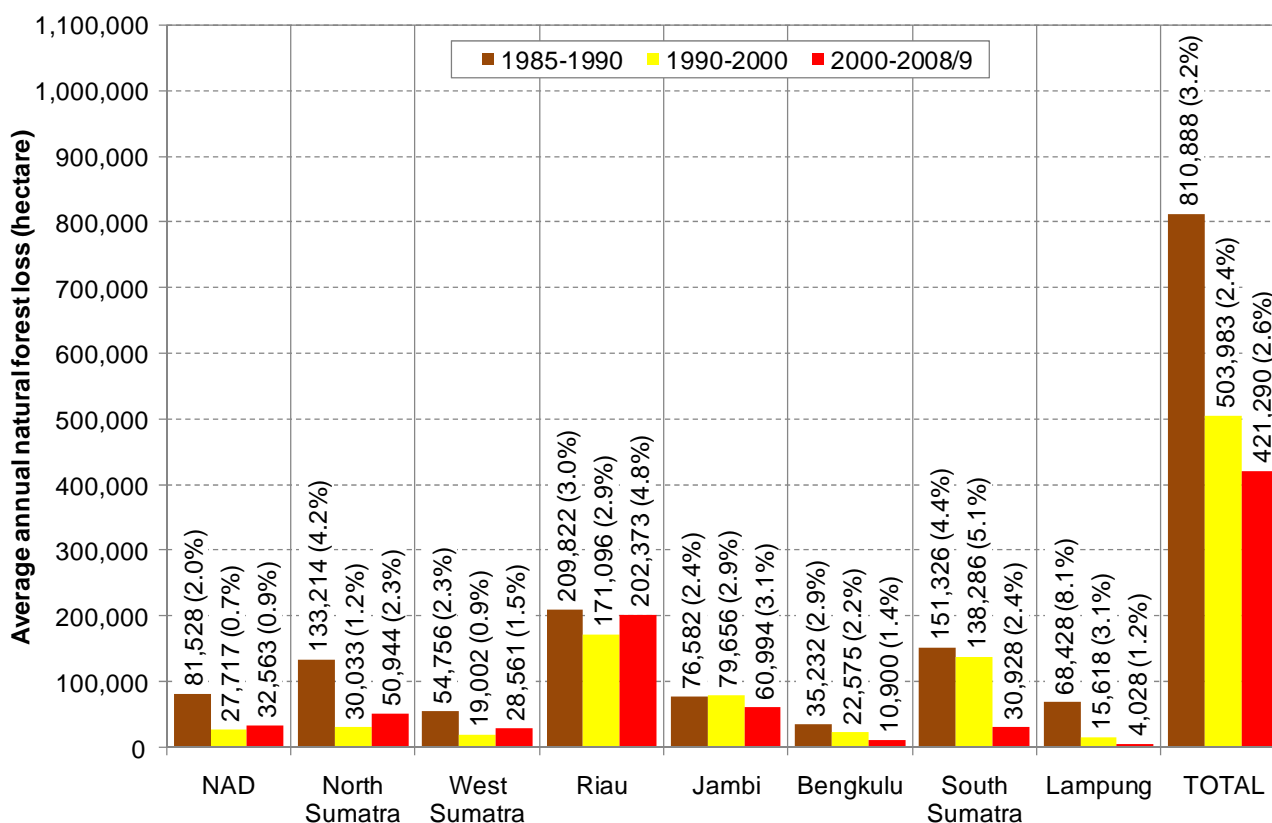
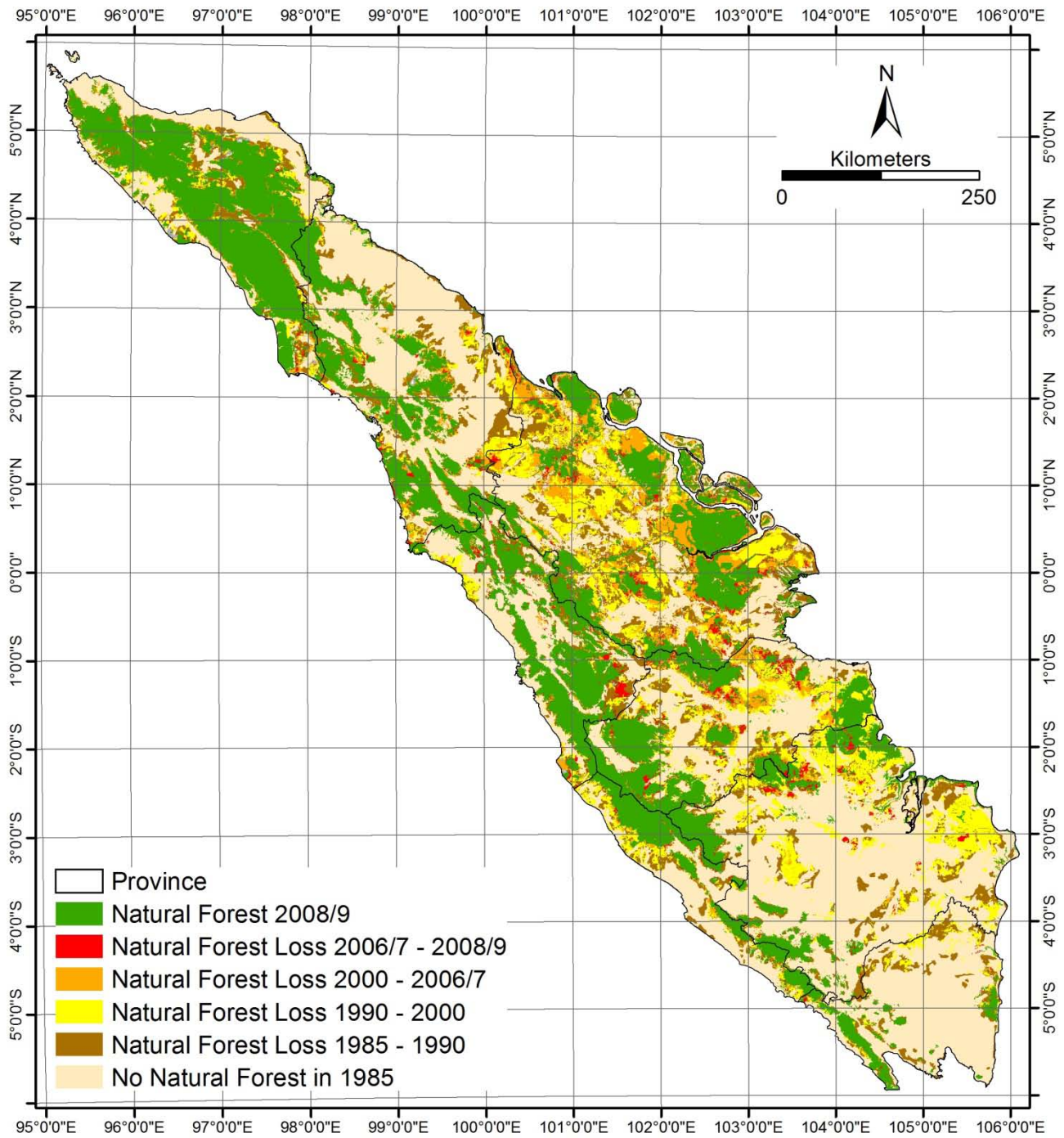


Figure 3.—Average annual natural forest loss in hectare and percentage over three study periods by province.

Natural forest clearance between 2000 and 2006/7 clearly concentrated in one single province, Riau (Map 6). The most recent natural forest clearance between 2006/7 and 2008/9 still focused on Riau but had spread to its neighboring provinces in central Sumatra (Map 6): Riau (380,143 ha, 35%), Jambi (199,712 ha, 19%), South Sumatra (152,657 ha, 14%) and West Sumatra (143,542 ha, 13%) together accounted for 81% of all Sumatran forest loss during those years.

Central Sumatra is home to one of the world's top pulp production centers with three huge mills who were expanding dramatically during the study period. Their wood supply was greatly affected by a police investigation into illegal logging by wood suppliers of the companies during 2007 and 2008, which stopped all pulp industry's natural forest wood sourcing during those two years in Riau Province. Neighboring provinces Jambi and North, West, and South Sumatra are within economic trucking and/or barging distance of the mills.



Map 6.—Natural forest remaining in Sumatra in 2008 (green) and lost in 1985-1990 (brown), 1990-2000 (yellow), 2000-2006/7 (orange) and 2006/7-2008/9 (red).

7. Loss of Carbon Stocks in Natural Forest and Peat

Sumatra's natural forest and peat soil are globally important carbon stores. However, the loss of Sumatra's natural forests and the decomposition and burning of deforested and/or drained peat soil over the past decades led to huge CO₂ emissions and contributed significantly to global climate change^{26, 27, 28, 29, 30}. In this chapter, we will look at the loss of Sumatra's natural forest and peat soil carbon and its significance for global climate change. Scientific knowledge and data on carbon stocks and emissions in general and specifically for Sumatra is still developing; therefore the estimates we describe below may severely over- or underestimate the actual emissions. However, we believe our estimates are correct at least within a 50% certainty range.

Carbon stocks of Sumatra's natural forest and peat soil

Forests sequester and store more carbon than any other terrestrial ecosystem; tropical forests are considered to store close to half of the world's living terrestrial carbon³¹. Because of the lack of forest-carbon values specific to Sumatra we used Intergovernmental Panel on Climate Change (IPCC)^{32, 33} default values of an average 350 tons of above-ground biomass (AGB) per hectare for tropical rain forests in Asia and its suggested 47 % carbon contained in that AGB for our calculations.

Applying IPCC values, Sumatra's 12.8 million ha of natural forest in 2008/9 contained 2.1 gigatons of carbon. Many of Sumatra's remaining natural forests have been logged, sometimes heavily, and those who are not burnt or otherwise cleared are regrowing fast. Even if these forests contain less biomass today than the IPCC assumes, their regrowth is continuously sequestering large amounts of carbon, as even mature, old-growth forests^{34, 35, 36, 37, 38} continue to do.

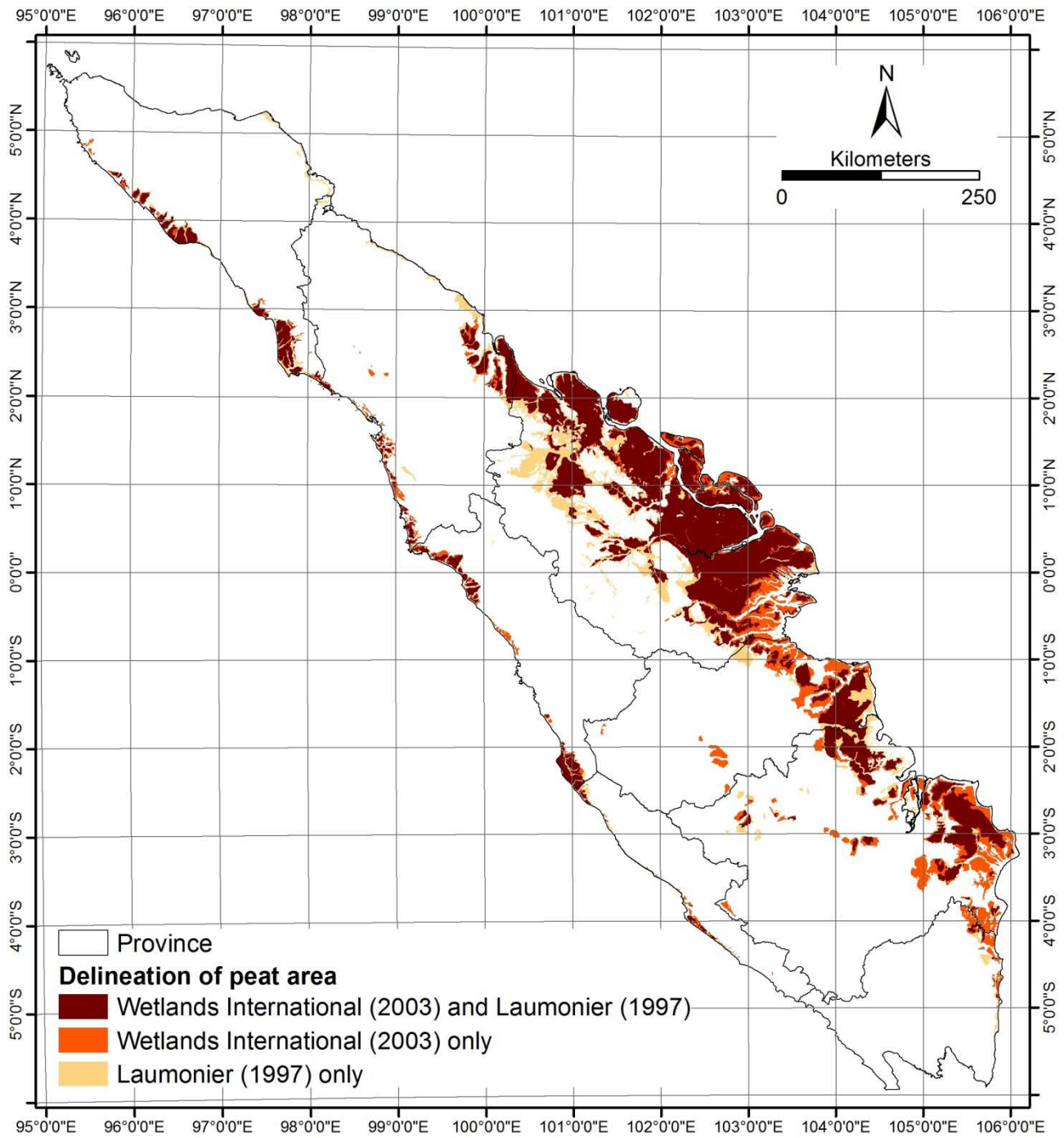
According to Wetlands International, Sumatra's 7.2 million ha peatlands contained 18.8 gigatons of carbon in 2002³⁹. That is 40% of Indonesia's (46.6 gigatons), 37% of Southeast Asia's (50.4 gigatons), 36% of the world's tropical (52.2 gigatons) and 4-9% of all global peatland carbon stores (202-500 gigatons)^{40, 41, 42, 43, 44}. Laumonier (1997) identified 1.7 million ha of peat areas beyond those mapped by Wetlands International^c, suggesting that Sumatra's peat carbon storage likely is even bigger (Map 7, see also Chapter 8). In addition to its existing carbon stores, all of Indonesia's peatland is believed to have a carbon sequestration potential of 15.3-17.6 megaton per year⁴⁵, 20-23% of the storage potential of all of the world's peatlands⁴⁶. Specific storage data for Sumatra are not available but the island's peatlands would likely be a very significant contributor to annual global carbon storage, in their undisturbed state.

In total, Sumatra stored up to 21 gigatons of carbon in its natural forests and peat in 2008/9 (Table 3). The distribution of these carbon stores differ greatly between Sumatra's provinces. Central Sumatra's provinces Riau, Jambi and South Sumatra have the highest carbon stores with 72%, 7.9% and 7.6% (Table 3 and Maps 7, 8).

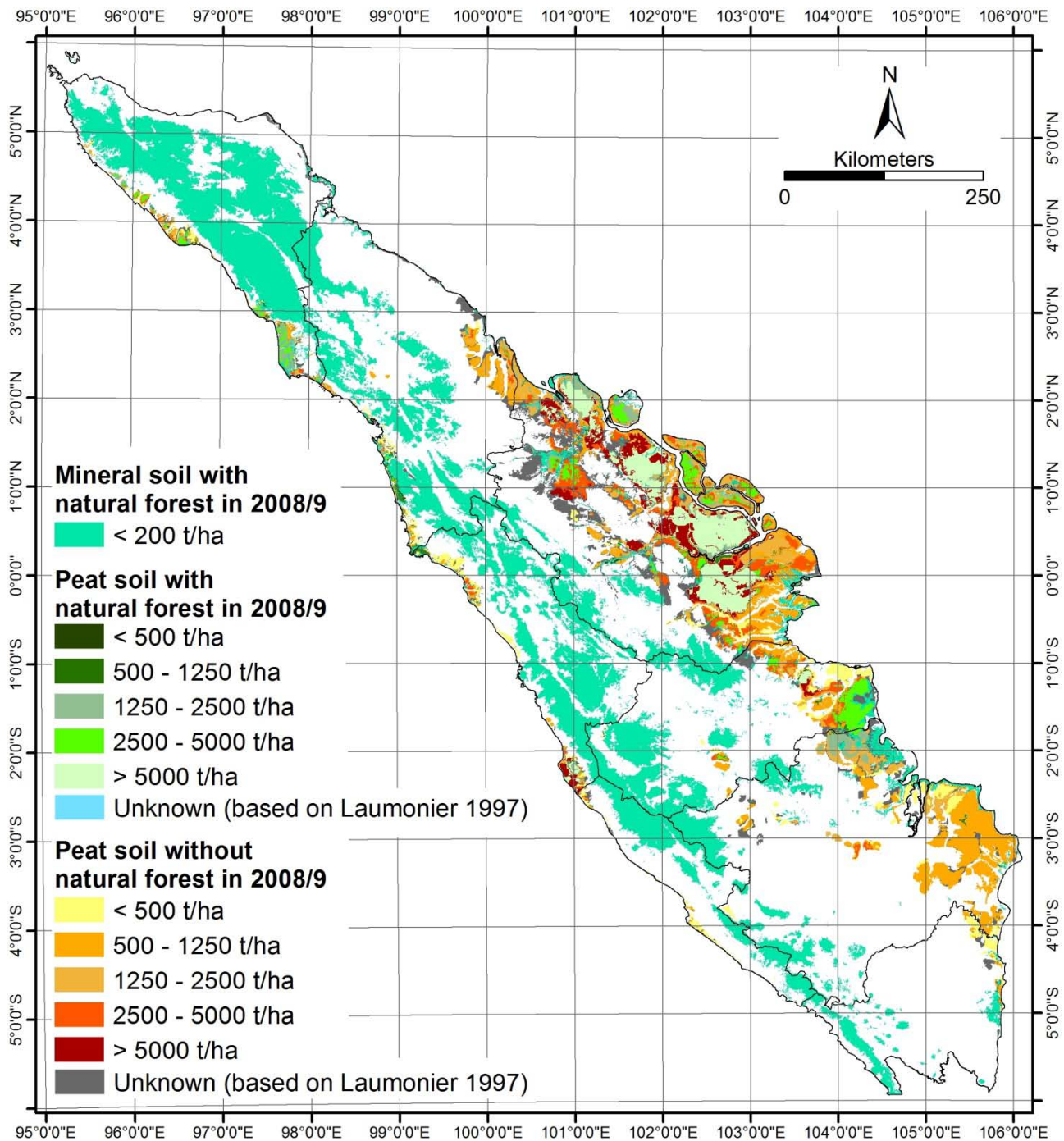
^c Delineated in three eco-floristic sectors associated with peat: Fresh Water Swamps, Mixed Peat Swamps and Peat Swamps (see Chapter 8)

Table 3.—Area (hectare) and carbon stock (megaton) of natural forest and peat soil in Sumatran provinces. Forest values are for Sumatra’s mainland only (our study area), peat carbon values include the small islands. Provinces are ranked by total natural carbon value.

	Natural Forest in 2008/9 (this study)			Peat in 2002 (Wetlands International, 2003)			Total Natural Carbon	
	Area (ha)	Carbon (Mt)	% Total	Area (ha)	Carbon (Mt)	% Total	(Mt)	% Total
Riau	2,566,630	422	20.0%	4,006,013	14,605	77.9%	15,027	72.0%
Jambi	1,479,838	243	11.6%	718,491	1,413	7.5%	1,656	7.9%
South Sumatra	1,055,447	174	8.2%	1,427,971	1,407	7.5%	1,581	7.6%
NAD	3,223,255	530	25.2%	281,870	459	2.4%	989	4.7%
West Sumatra	1,660,729	273	13.0%	211,469	422	2.3%	695	3.3%
North Sumatra	1,789,587	294	14.0%	349,435	377	2.0%	671	3.2%
Bengkulu	718,396	118	5.6%	52,421	31	0.2%	149	0.7%
Lampung	317,114	52	2.5%	90,293	36	0.2%	88	0.4%
TOTAL	12,810,997	2,107	100.0%	7,137,963	18,750	100.0%	20,857	100.0%



Map 7.—Peat areas identified by Wetlands International (2003) and in Laumonier (1997)'s peat associated Eco-Floristic Sectors (EFS) – Fresh Water Swamps, Mixed Peat Swamps and Peat Swamps (see Chapter 8).



Map 8.—Estimates of natural forest and peat carbon stocks (carbon ton per hectare) in Sumatra based on 2008/9 natural forest cover (this study) and peat areas identified by Wetlands International (2003). We assumed carbon stocks of natural forests to not exceed 200 tons/ha. We assumed carbon stocks of peat to be as estimated by Wetlands International (2003). We mapped additional peat areas (light blue and gray) following Laumonier (1997), but no peat carbon estimates are available for these areas.

Loss of Sumatra's natural forest and peat carbon stocks

Between 1985 and 2008, 12.5 million ha of natural forest were cleared in Sumatra (Chapter 6), emitting an estimated 7.5 gigatons (327 megatons per year) of CO₂ based on IPCC default values⁴⁷. Riau is by far the highest emitter of CO₂ from forest clearance (Table 4), the province caused 35% of Sumatra's total emissions between 1985 and 2008/9.

The Indonesian Ministry of Forestry estimated that the country emitted 257 megatons of CO₂ per year from deforestation (data, assumptions and period of time were not provided) and that Sumatra contributed 60% (154 megatons) of that⁴⁸. The emissions estimates for Sumatra are globally very significant with either estimates, accounting for either 10 or 20% of the 1.6 gigatons, the IPCC estimate of global annual average CO₂ emissions associated with land use change (primarily deforestation but without peat emissions) in the 1990s⁴⁹.

Table 4.—Average annual CO₂ emissions (megaton) from natural forest loss in Sumatra's provinces. Provinces are ranked by 1985 – 2008/9 average annual CO₂ emissions.

	1985-1990		1990-2000		2000-2008/9		1985-2008/9	
	CO ₂ (Mt)	%	CO ₂ (Mt)	%	CO ₂ (Mt)	%	CO ₂ (Mt)	%
Riau	126.6	25.9%	103.2	33.9%	122.1	48.0%	114.8	35.1%
South Sumatra	91.3	18.7%	83.4	27.4%	18.7	7.3%	62.6	19.1%
North Sumatra	80.4	16.4%	18.1	6.0%	30.7	12.1%	36.0	11.0%
NAD	49.2	10.1%	16.7	5.5%	19.6	7.7%	24.8	7.6%
Jambi	46.2	9.4%	48.0	15.8%	36.8	14.5%	43.7	13.4%
Lampung	41.3	8.4%	9.4	3.1%	2.4	1.0%	13.9	4.3%
West Sumatra	33.0	6.8%	11.5	3.8%	17.2	6.8%	18.2	5.6%
Bengkulu	21.3	4.3%	13.6	4.5%	6.6	2.6%	12.8	3.9%
TOTAL	489.1	100.0%	304.0	100.0%	254.1	100.0%	326.9	100.0%

In 1985, 85% of the island's 8.8 million-hectare peatlands (Wetlands International 2003 & Laumonier 1997) were covered by natural forest (7.5 million hectares), however, 5.0 million hectares of the natural forest were cleared by 2008/9. Much of the remaining 2.5 million ha of natural forest on peat has been logged or is being prepared and drained for clearing. Logging and clearing of peatland forest is always preceded by draining of the peat and clearing is often followed by burning. Both cause significant CO₂ emissions. The Indonesian Ministry of Forestry estimated that 1,061 megatons of CO₂ per year were emitted from Sumatra's peatlands through clearing, draining and burning between 1990 and 2002⁵⁰ based on Wetlands International (2003) data. Riau is by far the highest emitter of CO₂ from peat degradation and burning (Table 5), the province caused 65% of Sumatra's total peat emissions between 1990 and 2002.

Table 5.—Peat carbon stocks in 1990 and 2002, total carbon loss, total CO₂ emissions and average annual emissions by province (Wetlands International 2003).

	1990	2002	Total loss	Total emissions	Annual average emissions	
	Carbon (Mt)	Carbon (Mt)	Carbon (Mt)	CO ₂ (Mt)	CO ₂ (Mt)	% Total
Riau	16,851.2	14,605.0	2,246.2	8,236.0	686.3	64.9%
Jambi	1,851.0	1,413.1	437.9	1,605.5	133.8	12.6%
South Sumatra	1,729.3	1,407.2	322.1	1,180.9	98.4	9.3%
North Sumatra	560.7	377.3	183.4	672.4	56.0	5.3%
NAD	561.5	458.9	102.6	376.2	31.4	3.0%
West Sumatra	507.8	422.2	85.5	313.6	26.1	2.5%
Bengkulu	92.1	30.5	61.6	225.7	18.8	1.8%
Lampung	60.3	35.9	24.4	89.4	7.5	0.7%
TOTAL	22,213.8	18,750.2	3,463.6	12,699.7	1,058.3	100.0%

In summary, the Indonesian Ministry of Forestry estimated that Sumatra’s total annual CO₂ emissions from deforestation and peat were 1.22 gigatons per year⁵¹. Sumatra’s emissions thus exceeded the combined total of all annual emission reductions pledged under the Kyoto protocol (0.93 gigatons)⁵². Sumatra’s emissions are also equivalent to about three quarters of the whole world’s non peat land-use change emissions. Combining both this report’s data and the Ministry of Forestry’s data, we conclude that Riau may have contributed to around 60% of Sumatra’s total emissions from natural forest loss and peat drainage.

Continuing threats to Sumatra’s carbon and the global climate: The “Mega Pulp Project” disaster

Palm oil plantations are one of two key drivers of deforestation in Sumatra. They are difficult to map as government databases are out of date and incomplete. Detection of oil palm through remote sensing provides information on the status quo of plantings but does not indicate the threat posed by existing yet un-executed licenses. However, Sumatra’s remaining natural forests should, at least in theory, be relatively safe from conversion to licensed oil palm plantations as most by law should be inside land use zones which do not allow natural forest conversion to oil palm. Likely, the most severe oil palm threat to Sumatra’s natural forests is posed by so-called small-holders who illegally encroach even the highest value natural forests.

Industrial timber plantation concessions (HTI), which in Sumatra are almost exclusively “pulpwood plantations”, are the other key driver of deforestation on Sumatra (Map 9). Despite the fact that Sumatra’s flat, dry lowland forest is critically endangered (Chapters 6 and 8), HTI concessions converting these forests continue to be licensed and operated, further depleting the country’s carbon stocks. HTI today are the top threat to Sumatra’s natural forests as they traditionally have targeted areas with high standing timber volumes, good forests with high carbon stocks⁵³.

Our study showed the extreme environmental and climate threat posed by the pulp industry. In the 1990s, Central Kalimantan’s globally infamous “ex Mega Rice Project” cleared and drained a million hectares of peat and lowland swamp forest to unsuccessfully begin rice cultivation⁵⁴. For years, the Indonesian government, NGOs and donor agencies have been spending hundreds of millions of dollars to undo the climate disaster posed by that project. In the 2000s, unnoticed by most in its enormity, Sumatra quietly began building its own “Mega-Pulp Project” in the peatlands of Riau, Jambi, North, West and South Sumatra. Already totaling more than 2.2 million ha today, built on much deeper peat, and continuously expanding, Sumatra’s “Mega Pulp Project” is a climate disaster far worse than the ex Mega Rice Project⁵⁵.

The ex Mega Rice Project includes 920,000 hectares of >0.5m deep peat, of which 450,000 hectares are >3m deep⁵⁶. In contrast, Sumatra’s “Mega Pulp Project” includes close to two million hectares of >0.5m deep peat, of which at least 850,000 ha are 4 to 8 m deep and an additional 330,000 ha are 2 to 4 m deep (Table 6, Map 9). 65% (1.5 million ha) of the total area have already been deforested for development of severely draining pulpwood plantations. The remaining 35% (0.8 million ha) were still covered by natural forest in 2008/9 but could be converted any time.

Table 6.—Industrial Timber Plantation (HTI or “pulpwood plantation”) concessions in Sumatra’s peatlands (Wetlands International 2003 & Laumonier 1997), and their natural forest cover in 2008/9.

Peat depth (cm)	Natural Forest			No Natural Forest			Total	
	(ha)	(%)	(% total)	(ha)	(%)	(% total)	(ha)	(% total)
<50	1,554	23%	0%	5,339	77%	0%	6,893	0%
50 - 100	12,201	6%	2%	180,959	94%	12%	193,160	12%
100 - 200	111,977	18%	14%	494,649	82%	34%	606,626	34%
200 - 400	136,172	42%	17%	190,571	58%	13%	326,743	13%
400 - 800	486,024	57%	62%	363,517	43%	25%	849,541	25%
No info	40,011	15%	5%	221,185	85%	15%	261,196	15%
Total	787,939	35%	100%	1,456,220	65%	100%	2,244,159	100%

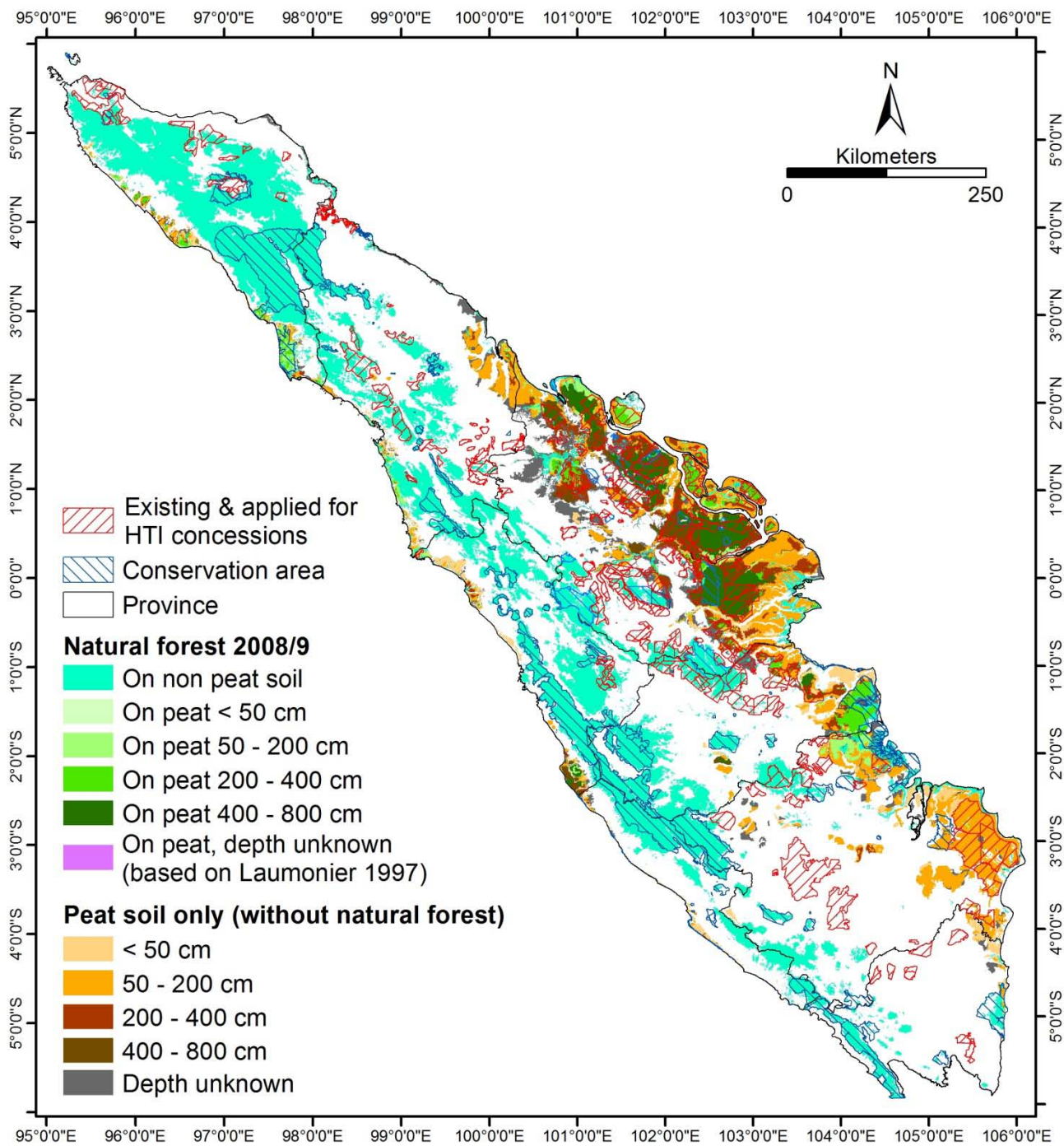
Worse than the sheer size of the “Mega Pulp Project” itself are the emissions it causes. Scientific life cycle comparisons of carbon budgets over a 25-year period have shown that pulpwood plantation development on peat soil causes more emissions per hectare than even the ex Mega Rice Project⁵⁷. The study compared (1) pristine, undrained peat swamp forest, (2) oil palm plantations, (3) pulpwood plantations (lifecycles of the latter two involve removal of the original natural forest, drainage, fire, harvesting and replanting) and (4) deforested, drained peatland that is affected by recurrent fire and is currently not being managed, the example of which was the ex Mega Rice Project. Acacia pulpwood tree plantations, degraded peatland, and oil palm plantations, respectively would cause 262, 214 and 147 tons per hectare per year of CO₂ emissions. As a result, peat of an average 4.4-meter thickness would disappear after 31 (5 acacia rotations), 38 and 55 years (2 oil palm rotations), respectively, after which the area might be inundated constantly and all plantation operations would cease⁵⁸. Flooded oil palm plantations on the deep peat along Riau’s Kerumutan peninsula are undeniable proof of this. Shallower peat would go extinct even sooner.

Riau is absolute leader in the “Sumatra Mega Pulp Project”, having allowed the conversion of 71% of the total area, having already developed 37% of all concession areas in Sumatra and threatening almost all of the natural peat forest still standing in all pulpwood plantation concessions (Map 9 and Table 7). In comparison, North and West Sumatra have very little area zoned as HTI, while Jambi and South Sumatra have only little natural forest left.

Table 7.—Pulpwood plantation (HTI) concessions on peat soil of more or less than 2 meters depth in Sumatra (Wetlands International 2003 & Laumonier 1997), with or without Natural forest in 2008/9 in four Sumatran provinces. Provinces are ranked by total area.

		Total Peat Area in HTI Concession				Already without Natural Forest in 2008/9			
		Peat < 2 m	Peat > 2 m	No info	Total	Peat < 2 m	Peat > 2 m	No info	Subt total
Riau	(ha)	269,099	1,118,803	199,477	1,587,380	158,608	504,001	164,924	827,532
	(% total)	12%	50%	9%	71%	7%	22%	7%	37%
South Sumatra	(ha)	497,633	0	22,508	520,141	488,055	0	22,088	510,143
	(% total)	22%	0%	1%	23%	22%	0%	1%	23%
Jambi	(ha)	35,883	57,481	33,835	127,199	33,054	50,087	29,948	113,090
	(% total)	2%	3%	2%	6%	1%	2%	1%	5%
North Sumatra	(ha)	578	0	5,375	5,954	490	0	4,225	4,715
	(% total)	0%	0%	0%	0%	0%	0%	0%	0%
West Sumatra	(ha)	3,485	0	0	3,485	740	0	0	740
	(% total)	0%	0%	0%	0%	0%	0%	0%	0%
TOTAL	(ha)	806,679	1,176,284	261,196	2,244,159	680,947	554,088	221,185	1,456,220
	(% total)	36%	52%	12%	100%	30%	25%	10%	65%

		Still with Natural Forest in 2008/9			
		Peat < 2 m	Peat > 2 m	No info	Subt total
Riau	(ha)	110,492	614,802	34,554	759,848
	(% total)	5%	27%	2%	34%
South Sumatra	(ha)	9,578	0	420	9,998
	(% total)	0%	0%	0%	0%
Jambi	(ha)	2,829	7,394	3,887	14,110
	(% total)	0%	0%	0%	1%
North Sumatra	(ha)	89	0	1,150	1,239
	(% total)	0%	0%	0%	0%
West Sumatra	(ha)	2,745	0	0	2,745
	(% total)	0%	0%	0%	0%
TOTAL	(ha)	125,732	622,197	40,011	787,939
	(% total)	6%	28%	2%	35%



Map 9.—Natural forest and peat soil (by depth) and pulpwood plantation concessions in Sumatra.

The 72% of Sumatra’s peatlands no longer covered by natural forest today are all being constantly drained and are causing significant carbon emissions, quickly through burning or slowly through decomposition of the peat soil. Burning is the most dramatic visible sign of rapid CO₂ emissions from peat carbon stores. Widespread fire hotspots⁵⁹ and blankets of haze covering large parts of Sumatra, Malaysia and Singapore in 2009 showed that the island’s impact on the global climate is clear and present. But all development of peat based on drainage of the soil leads to lowered water tables and thus dry and oxidative conditions that cause emission of all stored carbon through decomposition, continuously, silently, and without the drama of fire and haze. Fighting peat fires does not mean that emissions stop. And, once developed, the peat’s ability to sequester carbon and scrub CO₂ out of the world’s atmosphere is severely impaired or even destroyed⁶⁰.

The rush to promote biofuels from palm oil and possibly soon cellulose poses another threat to Sumatra’s forest and peat carbon stores and the global climate. Several major Indonesian palm oil producers have

installed large capacities for biofuel production in Sumatra, especially in Riau, the country's palm oil epicenter. Yet it would take between 75 and 93 years for fossil-fuel carbon emissions saved through the use of palm oil biofuel to compensate for the carbon emissions generated by the natural forest conversion necessary to develop the oil palm plantations. If the palm oil plantation was created on peat with a soil carbon stock of 1,550 tons per hectare, palm oil biofuel would take an additional 600 years to compensate with emission savings for the forest and peat destruction it caused⁶¹.

Sumatra's forest conversion industries publicly mislead about these threats. Recently, one of Sumatra's pulp & paper companies, a major driver of deforestation and peat degradation, began to claim that it is "near carbon neutral." The company added the carbon sequestration of its acacia pulp wood plantations into its "carbon foot print" formula while ignoring its massive clearing of natural forests to create these plantations and the unmitigated draining of peat soils to operate them⁶². Such carbon-neutrality claims are fraudulent and irresponsible misleading of consumers^{63, 64} and government decision-makers alike.

Survival of Sumatra's peat lands and protection of its carbon stores

The continuing loss of natural forests and degradation and burning of Sumatra's peat directly and significantly counter global efforts to reduce greenhouse gas emissions. The world has taken increasing interest in reducing emissions from peat through rehabilitation, because of the very positive cost-benefit ratio. However, it should not be forgotten that carbon emissions from clearing of Sumatra's non peat forest are also globally significant and should be stopped. The emission reduction and cost of rehabilitation of already degraded areas are as yet unclear, whereas the value of emission avoided by preventing further development and degradation is very clear.

The mitigation of the huge future emissions from peat will depend on the health of the natural forests covering the island's peat soil today. Only then will the long-term storage of Sumatra's carbon stocks be ensured. Any form of land use on peat that involves construction of infrastructure (canals, roads), removal of peatland forest and preparation of peat soil for pulpwood, oil palm or other crop production through drainage and fire, followed by permanent lowering of the water table and regular harvesting of the planted crops, leads to the loss of peat soil through carbon emissions. Only unlogged, undrained peatland forest has a positive carbon balance⁶⁵. The simplest and most effective measures to prevent further decomposition and burning of peat are conservation of remaining peatland forests and rehabilitation of degraded peatland forests and peat by respecting the hydrological catchment areas of each peat landscape^{66 67}. Full protection of the remaining peatland forests is the only management practice that would ensure recovery (over 50 years or more) and eventual increase of biomass and thus carbon stores as peat soil accrues. Focusing on extinguishing peatland fires while continuing land use as usual will not stop carbon emissions. It merely means that it will take longer for the landscape's carbon resources to be released into the atmosphere. Total emissions and impact on the global climate over time would be the same⁶⁸.

As we showed, the emissions from deforestation and peat degradation in Sumatra have been dramatic in recent years and the likely emissions over the next few years from licensed but not yet developed concessions will be huge. Sealing Sumatra's peat carbon stocks today would have the most dramatic and most immediate effect on climate mitigation and, compared to industrial climate mitigation approaches, would likely come at a fraction of the cost per unit CO₂. The simplest and most effective measures to prevent emissions from peat are conservation of remaining peatland forests, rehabilitation of degraded peatland forests, restoration of cleared peat forest, and rehabilitation of peat soils respecting the hydrological catchment areas of each peat landscape. Indonesia estimated its BAU emissions for 2020 as 2.9 Gt CO₂⁶⁹. Thus Indonesia's commitment to reduce emissions by 26% would mean a reduction of 750 Mt. Achieving "zero-emissions" in Riau Province's Kampar / Kerumutan Landscape alone could reduce emissions by up to 407 Mt CO₂ per year, equivalent to 54% of the reduction target.

8. Loss of Eco-Floristic Diversity in Sumatra

Sumatra is Indonesia's only island whose eco-floristic diversity has been studied in great detail. In this Chapter, we will look at the degradation of this diversity through deforestation.

Stratification of Sumatra into thirty-eight Eco-Floristic Sectors

Laumonier and collaborators conducted 10 years of intensive vegetation surveys in Sumatra in the 1980s. They combined biogeographical studies and a hierarchical ecological classification of Sumatra's forests with tree species distribution and delineated 38 eco-floristic sectors (EFSs) representing unique ecosystems distinguished by their tree flora and environmental parameters^{70, 71} (Table 8). This approach was developed by biogeography and vegetation schools^{72, 73, 74}, was recommended by UNESCO⁷⁵ and FAO^{76, 77}, and has inspired the IUCN-WWF centres of plant diversity⁷⁸. Sumatra's eco-floristic sectors were grouped into six "natural regions" (western regions, mountains, eastern hills and piedmonts, eastern peneplains, swamp and non-swamp), following Verstappen (1973)⁷⁹. Within each region elevation was a measure used in the stratification of the sectors. Distinct boundaries occurred at various elevations listed in Table 9.

Table 8.—Sumatra's 38 Eco-Floristic Sectors (EFSs) and their general elevation. Zonal EFSs were listed from west to east, north to south.

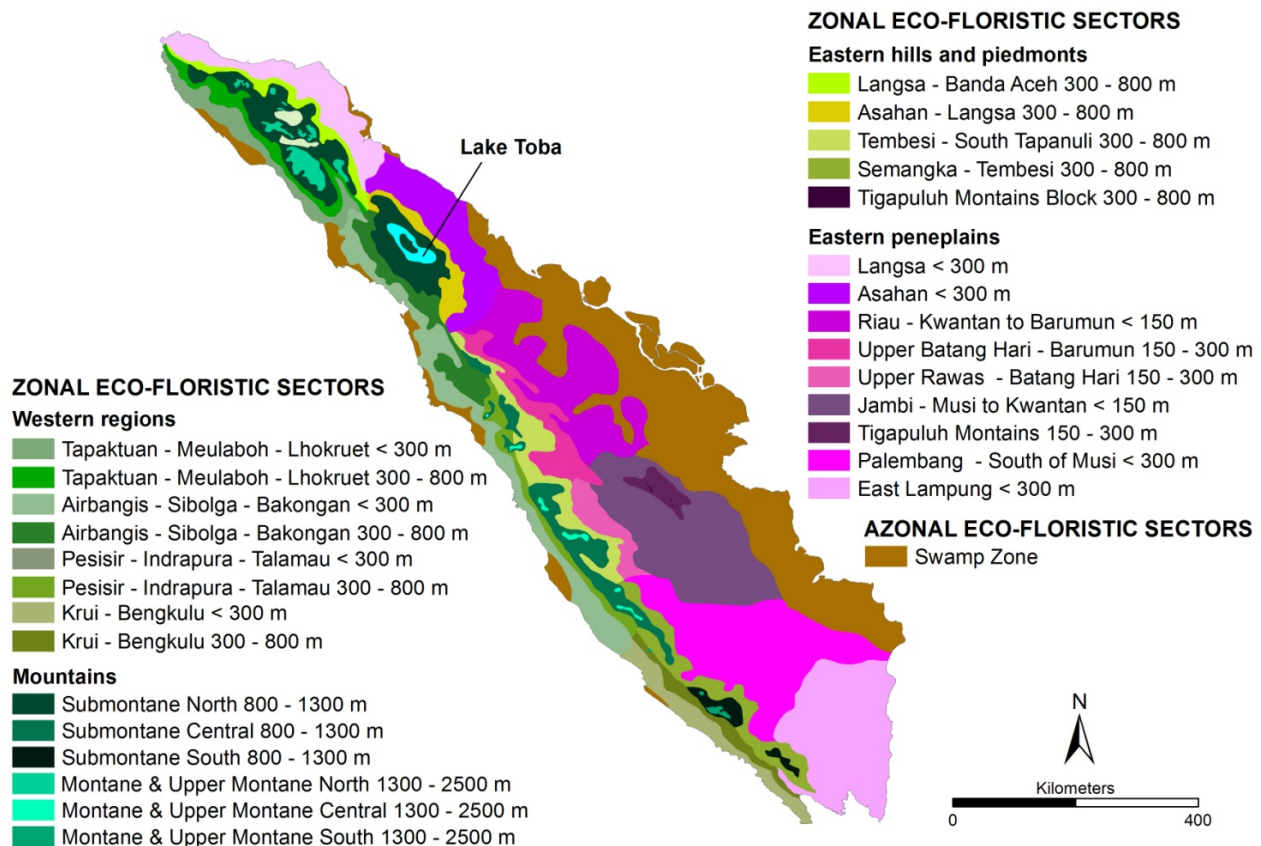
No.	Eco-Floristic Sector	Elevation	No.	Eco-Floristic Sector	Elevation
ZONAL ECO-FLORISTIC SECTORS (No. 1-29)			Eastern peneplains (No. 21-29)		
<i>Western regions (No. 1-8)</i>			21	Langsa < 300 m	< 300
1	Tapaktuan - Meulaboh - Lhokruet < 300 m	< 300	22	Asahan < 300 m	< 300
2	Tapaktuan - Meulaboh - Lhokruet 300 - 800 m	300 - 800	23	Riau - Kwantan to Barumon < 150 m	< 150
3	Airbangis - Sibolga - Bakongan < 300 m	< 300	24	Upper Batang Hari - Barumon 150 - 300 m	150 - 300
4	Airbangis - Sibolga - Bakongan 300 - 800 m	300 - 800	25	Upper Rawas - Batang Hari 150 - 300 m	150 - 300
5	Pesisir - Indrapura - Talamau < 300 m	< 300	26	Jambi - Musi to Kwantan < 150 m	< 150
6	Pesisir - Indrapura - Talamau 300 - 800 m	300 - 800	27	Tigapuluh Mountains 150 - 300 m	150 - 300
7	Krui - Bengkulu < 300 m	< 300	28	Palembang - South of Musi < 300 m	< 300
8	Krui - Bengkulu 300 - 800 m	300 - 800	29	East Lampung < 300 m	< 300
<i>Mountains (No. 9-15)</i>			AZONAL ECO-FLORISTIC SECTORS (No. 30-38)		
9	Submontane North 800 - 1300 m	800 - 1300	<i>Swamp (No. 30-34)</i>		
10	Submontane Central 800 - 1300 m	800 - 1300	30	Mangroves Swamps	0
11	Submontane South 800 - 1300 m	800 - 1300	31	Fresh Water Swamps	1 - 5
12	Montane & Upper Montane North 1300 - 2500 m	1300 - 2500	32	Mixed Peat Swamps	2 - 5
13	Montane & Upper Montane Central 1300 - 2500 m	1300 - 2500	33	Peat Swamps	5 - 10
14	Montane & Upper Montane South 1300 - 2500 m	1300 - 2500	34	Montane Swamp Vegetation 1000 - 1200 m	1000 - 1200
15	Tropalpine > 2500 m	> 2500	<i>Non-Swamp (No. 35-38)</i>		
<i>Eastern hills and piedmonts (No. 16-20)</i>			35	Limestone 300 - 800 m	300 - 800
16	Langsa - Banda Aceh 300 - 800 m	300 - 800	36	Coastal	0 - 5
17	Asahan - Langsa 300 - 800 m	300 - 800	37	Man-made Takengon Pine Forest 500 - 800 m	500 - 800
18	Tembesi - South Tapanuli 300 - 800 m	300 - 800	38	Riparian Forest	2 - 800
19	Semangka - Tembesi 300 - 800 m	300 - 800			
20	Tigapuluh Mountains 300 - 800 m	300 - 800			

Laumonier defined the EFSs through a combination of biogeographical analysis and stratification of ecological factors:

- **Bioclimates** considered variations in intensity of rainfall, rainfall regimes, temperature of the coldest month and intensity of the dry season.

- **Geology** considered especially substrates developed on recent or old alluvium, peat deposits, recent or old volcanic rocks, granites and sedimentary, metamorphic or intrusive rocks.
- **Physiography and geomorphology** considered units such as land systems and land units, where vegetation could have been influenced by fragmentation and isolation caused by river system development or tectonic and volcanic activity.

EFSs were named according to dominant volcanoes, larger rivers, and large towns or provinces in the area. For the purpose of clarity and due to scale of representation, only the general distribution of Sumatra's EFSs were shown in Map 10, some EFSs were omitted: (1) five EFSs in the “swamp” natural region, in which important eco-floristic distinctions were made, (2) Tropicline > 2500 m in “mountains” natural region and (3) four EFSs in “non-swamp” natural region, which were ecologically important, but occupied very small areas.



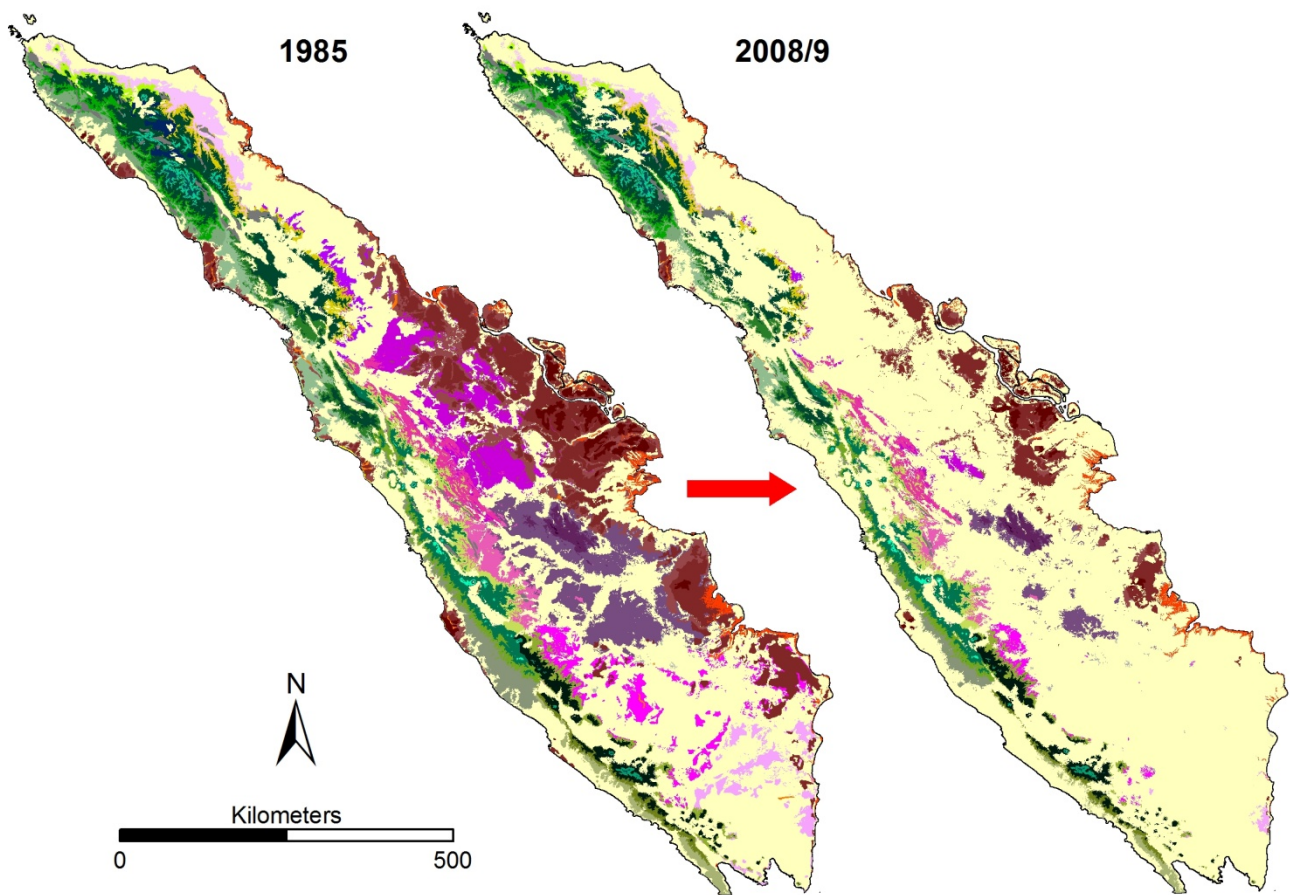
Map 10.—Generalized zonation of Sumatra based on Eco-Floristic Sectors in seven natural regions.

Loss of natural forest in Sumatra's eco-floristic sectors and their extinction risks

By 2008, some EFSs had lost more than 90% of their 1985 natural forest cover, while others had not lost any (Map 11 and Table 9). The forests in individual EFSs clearly faced different levels of extinction risk. We followed the IUCN nomenclature for threatened species categories and defined five “extinction risk categories” for eco-floristic sectors based on the percentage of 1985 natural forest that had been lost in the respective EFS by 2008/9 (Map 11 and Table 9)^d:

- **Critically Endangered:** EFS had lost more than 70% of 1985 natural forest by 2008/9
- **Endangered:** EFS had lost 50 to 70% of 1985 natural forest by 2008/9
- **Vulnerable:** EFS had lost 40 to 50% of 1985 natural forest by 2008/9
- **Near Threatened:** EFS had lost 20 to 40% of 1985 natural forest by 2008/9
- **Least Concern:** EFS had lost less than 20% of 1985 natural forest by 2008/9

^d A few EFS changed their category since Laumonier et al. (2010) paper was published since forest cover 2006/7 were corrected based on 2008/9.



Natural forest covers in EFS

Western regions

- Tapaktuan - Meulaboh - Lhokruet < 300 m
- Tapaktuan - Meulaboh - Lhokruet 300 - 800 m
- Airbangis - Sibolga - Bakongan < 300 m
- Airbangis - Sibolga - Bakongan 300 - 800 m
- Pesisir - Indrapura - Talamau < 300 m
- Pesisir - Indrapura - Talamau 300 - 800 m
- Krui - Bengkulu < 300 m
- Krui - Bengkulu 300 - 800 m

Mountains

- Submontane North 800 - 1300 m
- Submontane Central 800 - 1300 m
- Submontane South 800 - 1300 m
- Montane & Upper Montane North 1300 - 2500 m
- Montane & Upper Montane Central 1300 - 2500 m
- Montane & Upper Montane South 1300 - 2500 m
- Tropalpine > 2500 m

Eastern hills and piedmonts

- Langsa - Banda Aceh 300 - 800 m
- Asahan - Langsa 300 - 800 m
- Tembesi - South Tapanuli 300 - 800 m
- Semangka - Tembesi 300 - 800 m
- Tigapuluh Mountains 300 - 800 m

Eastern peneplains

- Langsa < 300 m
- Asahan < 300 m
- Riau - Kwantan to Barumon < 150 m
- Upper Batang Hari - Barumon 150 - 300 m
- Upper Rawas - Batang Hari 150 - 300 m
- Jambi - Musi to Kwantan < 150 m
- Tigapuluh Mountains 150 - 300 m
- Palembang - South of Musi < 300 m
- East Lampung < 300 m

Swamp

- Mangroves Swamps
- Fresh Water Swamps
- Mixed Peat Swamps
- Peat Swamps
- Montane Swamp Vegetation 1000 - 1200 m

Non-Swamp

- Limestone 300 - 800 m
- Coastal
- Man-made Takengon Pine Forest 500 - 800 m
- Riparian Forest

No natural forest

- No natural forest

Map 11.—Natural forest cover loss in Sumatra’s eco-floristic sectors between 1985 and 2008/9.

Table 9.—Loss of natural forest cover 1985-2008 in each eco-floristic sector and their conservation status based on percentage of natural forest loss since 1985 (Critically Endangered: red, Endangered: orange, Vulnerable: yellow, Near Threatened: light green and Least Concern: dark green).

No.	Eco-Floristic Sector	Elevation Class	Natural Forest		Natural Forest Loss 1985-2008/9		Extinction Risk Category
			1985	2008/9	Loss 1985-2008/9	(%)	
			(ha)	(ha)	(ha)	(%)	
<i>Western regions (No. 1-8)</i>							
1	Tapakuan - Meulaboh - Lhokruet < 300 m	< 300	534,073	368,808	165,265	31%	NT
2	Tapakuan - Meulaboh - Lhokruet 300 - 800 m	300-800	465,076	424,673	40,402	9%	LC
3	Airbangis - Sibolga - Bakongan < 300 m	< 300	598,211	351,822	246,389	41%	VU
4	Airbangis - Sibolga - Bakongan 300 - 800 m	300-800	468,956	354,830	114,126	24%	NT
5	Pesisir - Indrapura - Talamau < 300 m	< 300	626,704	315,330	311,374	50%	EN
6	Pesisir - Indrapura - Talamau 300 - 800 m	300-800	394,700	361,555	33,145	8%	LC
7	Krui - Bengkulu < 300 m	< 300	319,525	161,963	157,562	49%	VU
8	Krui - Bengkulu 300 - 800 m	300-800	238,658	178,991	59,666	25%	NT
<i>Mountains (No. 9-15)</i>							
9	Submontane North 800 - 1300 m	800 - 1300	1,917,250	1,665,792	251,458	13%	LC
10	Submontane Central 800 - 1300 m	800 - 1300	842,913	789,200	53,713	6%	LC
11	Submontane South 800 - 1300 m	800 - 1300	602,847	502,652	100,195	17%	LC
12	Montane & Upper Montane North 1300 - 2500 m	1300 - 2500	199,273	197,657	1,616	1%	LC
13	Montane & Upper Montane Central 1300 - 2500 m	1300 - 2500	44,885	44,279	607	1%	LC
14	Montane & Upper Montane South 1300 - 2500 m	1300 - 2500	38,017	37,991	26	0%	LC
15	Tropicalpine > 2500 m	> 2500	79,968	79,497	471	1%	LC
<i>Eastern hills and piedmonts (No. 16-20)</i>							
16	Langsa - Banda Aceh 300 - 800 m	300 - 800 m	151,406	123,121	28,285	19%	LC
17	Asahan - Langsa 300 - 800 m	300 - 800 m	434,396	350,342	84,054	19%	LC
18	Tembesi - South Tapanuli 300 - 800 m	300 - 800 m	639,672	544,025	95,647	15%	LC
19	Semangka - Tembesi 300 - 800 m	300 - 800 m	375,474	255,079	120,395	32%	NT
20	Tigapuluh Mountains 300 - 800 m	300 - 800 m	5,011	4,995	16	0%	LC
<i>Eastern peneplains (No. 21-29)</i>							
21	Langsa < 300 m	< 300	674,025	403,625	270,400	40%	VU
22	Asahan < 300 m	< 300	261,673	57,129	204,544	78%	CR
23	Riau - Kwantan to Barumun < 150 m	< 150	1,612,036	149,720	1,462,316	91%	CR
24	Upper Batang Hari - Barumun 150 - 300 m	150 - 300	648,133	447,051	201,082	31%	NT
25	Upper Rawas - Batang Hari 150 - 300 m	150 - 300	524,876	280,799	244,077	47%	VU
26	Jambi - Musi to Kwantan < 150 m	< 150	2,448,801	549,942	1,898,859	78%	CR
27	Tigapuluh Mountains 150 - 300 m	150 - 300	222,892	207,850	15,042	7%	LC
28	Palembang - South of Musi < 300 m	< 300	996,837	225,117	771,720	77%	CR
29	East Lampung < 300 m	< 300	614,033	59,285	554,748	90%	CR
<i>Swamp (No. 30-34)</i>							
30	Mangroves Swamps	0	595,903	444,055	151,848	25%	NT
31	Fresh Water Swamps	1 - 5	2,450,357	589,661	1,860,696	76%	CR
32	Mixed Peat Swamps	2 - 5	3,943,918	1,511,042	2,432,876	62%	EN
33	Peat Swamps	5 - 10	506,848	250,753	256,095	51%	EN
34	Montane Swamp Vegetation 1000 - 1200 m	1000 - 1200	2,331	676	1,655	71%	CR
<i>Non-Swamp (No. 35-38)</i>							
35	Limestone 300 - 800 m	300 - 800	414,037	340,919	73,118	18%	LC
36	Coastal	0 - 5	15,340	4,192	11,148	73%	CR
37	Man-made Takengon Pine Forest 500 - 800 m	500 - 800	143,646	26,074	117,572	82%	CR
38	Riparian Forest	2 - 800	54,849	11,166	43,684	80%	CR

By 2008/9, 17 out of Sumatra's 38 eco-floristic sectors (EFSs) had become 'critically endangered', 'endangered', or 'vulnerable'. Eighty-seven percent of all Sumatran forest loss occurred in these EFSs. Almost forty % of all natural forest in 2008/9 remained in these EFSs. 87% of Sumatra's all natural forest loss (10.8 million ha) happened in these EFSs. 39% of all natural forest remaining in Sumatra (4.9 million ha) in 2008/9 were in these EFSs, many of them in Sumatra's "eastern penneplains", "swamp" and "non-swamp" natural regions (Table 4, Table 10 and Map 12). Most of the forest loss occurred in EFSs with an elevation of less than 150 meters (Chapter 6).

Table 10.—Loss of natural forest in eco-floristic sectors by extinction risk category or by natural region.

Eco-Floristic Sector by Extinction Risk Category	Natural Forest			1985 - 2008/9 loss	
	1985	2008/9		(ha)	(% Total)
	(ha)	(ha)	(% Total)		
Critically Endangered	8,599,903	1,672,962	13.2%	6,926,942	55.7%
Endangered	4,450,765	1,761,794	13.9%	2,688,971	21.6%
Vulnerable	2,743,340	1,513,538	11.9%	1,229,802	9.9%
Near Threatened	2,861,196	2,048,814	16.2%	812,383	6.5%
Least Concern	6,452,342	5,674,547	44.8%	777,795	6.3%
Total	25,107,547	12,671,655	100.0%	12,435,891	100.0%

Eco-Floristic Sector by Extinction Risk Category	Natural Forest			1985 - 2008/9 loss	
	1985	2008/9		(ha)	(% Total)
	(ha)	(ha)	(% Total)		
Western region	3,645,902	2,517,972	19.9%	1,127,929	9.1%
Mountains	3,725,153	3,317,068	26.2%	408,085	3.3%
Eastern hills and piedmonts	1,605,959	1,277,562	10.1%	328,397	2.6%
Eastern penneplains	8,003,305	2,380,517	18.8%	5,622,788	45.2%
Swamp	7,499,356	2,796,186	22.1%	4,703,170	37.8%
Non-Swamp	627,872	382,350	3.0%	245,522	2.0%
Total	25,107,547	12,671,655	100.0%	12,435,891	100.0%

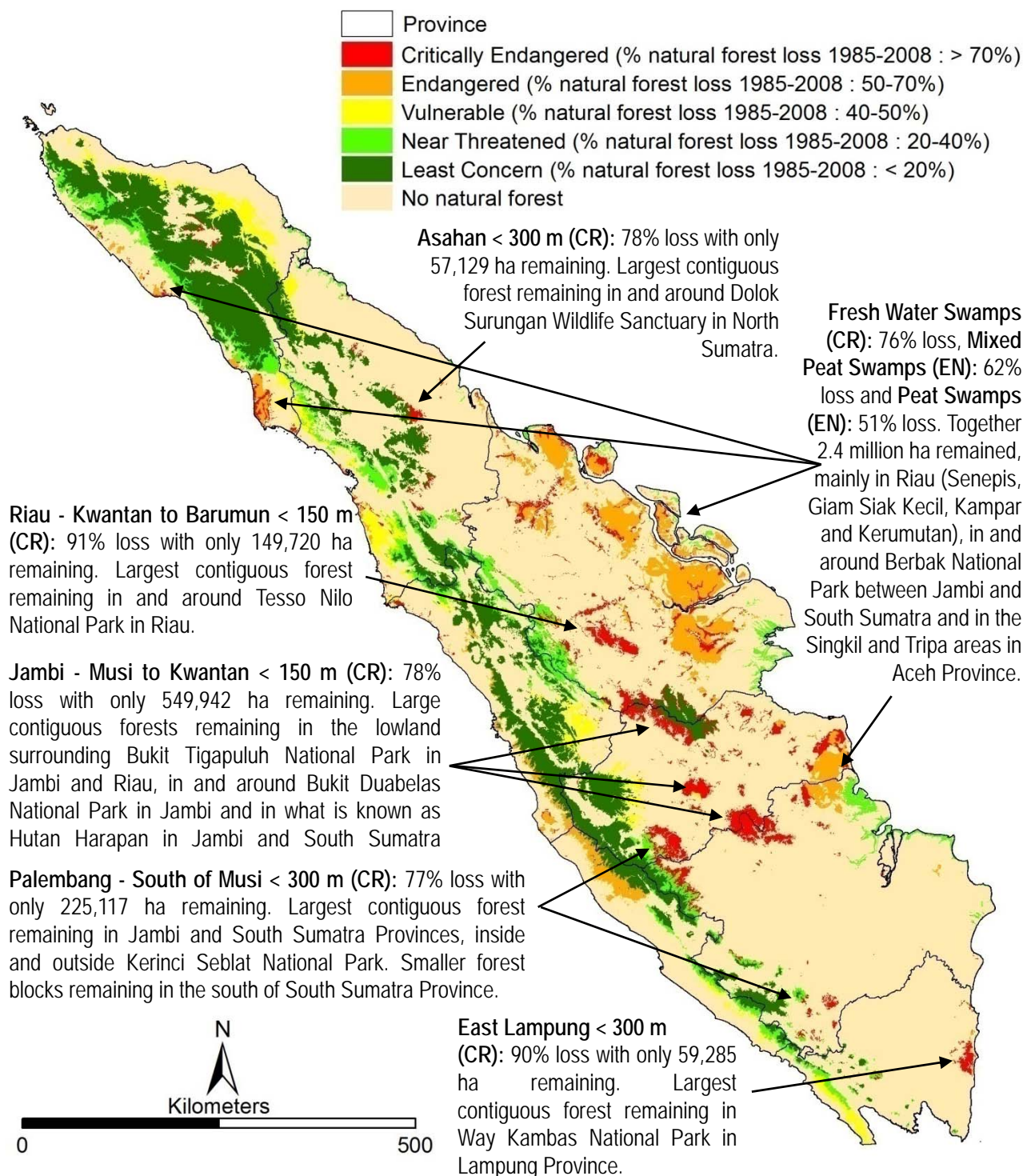
The remaining forests in selected "critically endangered" and "endangered" EFSs were highlighted in Map 12. The following four EFSs were also critically endangered or endangered, but because of their very restricted distribution could not easily be shown on this small map (Table 10):

- **Montane Swamp Vegetation 1000 - 1200 m:** 71% was lost and only 676 hectares remained in Jambi.
- **Riparian Forest:** 80% was lost and only 11,166 hectares remained in 2008 in various provinces.
- **Man-made Takengon Pine Forest 500 - 800 m:** 82% was lost and only 26,074 hectares remained in Aceh.
- **Coastal:** 73% was lost and 4,192 hectares remained in various provinces.

"Vulnerable" EFRs included:

- **Airbangis-Sibolga-Bakongan < 300 m:** 41% was lost and 351,822 hectares remained in Aceh, North Sumatra and West Sumatra.
- **Krui-Bengkulu < 300 m:** 49% was lost and 161,963 hectares remained in Bengkulu, South Sumatra and Lampung.
- **Langsa < 300 m:** 40% was lost and 403,625 hectares remained in Aceh and North Sumatra.
- **Upper Rawas-Batang Hari 150 - 300 m:** 47% was lost and 280,799 hectares remained in West Sumatra, Riau and Jambi.

Natural forest in all EFSs in Sumatra's "mountains" and "eastern hills and piedmonts" natural regions were "near threatened" or of "least concern" (Table 9). They were either legally protected or, if not, they seemed to have been left alone because of high elevation and terrain features that made them difficult to access and develop by the forest conversion industries or local people. However, once the natural forests of critically endangered, endangered and vulnerable EFSs are gone, less-accessible forests will become the next targets.



Map 12.—All natural forest remaining in Sumatra in 2008, color-coded to reflect the risk that the forests in any given eco-floristic sector will go extinct. Largest contiguous natural forest areas in critically endangered (CR) and endangered (EN) EFSs are highlighted.

Survival requirements

Eco-floristic sectors represent Sumatra's original floristic diversity within (alpha) and between (beta) ecosystems. Alpha diversity refers to the diversity within a particular area or ecosystem, usually expressed as the number of species (i.e., species richness) in that ecosystem⁸⁰. Beta diversity refers to the change in species diversity between ecosystems, expressed as the total number of species that are unique to each of the ecosystems being compared⁸¹. Full representation of all EFS is essential to preserve the original diversity of

Sumatra's eco-floristic systems. Yet, extinction risks and vulnerability to future threats are high in many EFSs and some may soon be lost.

Island, provincial and district land-use planning processes should consider EFS delineations presented here as a premier first-level decision making tool (Chapter 10) for the designation of urgently needed new conservation and forest restoration areas that would mitigate the imminent threats to the island's original biodiversity and prevent EFS extinction⁸².

9. Decline of Sumatra's Four Flagship Species: Elephant, Orangutan, Tiger and Rhino

As Sumatra's natural forests have disappeared, so have the animals they harbor. In this chapter, we will look at the decline of Sumatra's charismatic mega-fauna, its four endemic flagship species: the Sumatran elephant, orangutan, tiger and rhino.

9.1. Sumatran Elephant (*Elephas maximus spp. sumatranus*) 2008 IUCN Red List of Threatened Species Category: Endangered⁸³ CITES: Appendix I⁸⁴

The Sumatran elephant is a subspecies of the Asian elephant found only on the Indonesian island of Sumatra. Its highest current total population estimate is 2,800, though there have not been any systematic island-wide surveys. Between 1985 and 2007, the population is believed to have declined up to 50%.

Populations

1985: An island-wide rapid survey suggests that between 2,800 and 4,800 elephants live in the wild in 43 ranges in all eight mainland provinces⁸⁵ of Sumatra. Riau Province is believed to have the largest elephant population in Sumatra.

2007: Guesstimates suggest that between 2,400 and 2,800 elephants live in the wild⁸⁶. Given the very high number of elephants brought into captivity since 1985⁸⁷, the high mortality experienced during these government capture-and-translocation operations⁸⁸, and the high numbers of elephants lost to retaliatory killing after human-elephant conflict⁸⁹ and poaching (based on local newspaper reports), it is highly likely that Sumatra's total population size in 1985 might actually have been greater than even that year's high estimate of 4,800 elephants suggests. In any case, in only one generation – between 1985 and 2007 – Sumatra may have lost up to 50% of its elephants.

2008: By 2008, elephants had become locally extinct in 23 of the 43 ranges identified in Sumatra in 1985 (Map 13), indicating a very significant decline of the Sumatran elephant population since then. The elephant is locally extinct in one of Sumatra's eight mainland provinces (West Sumatra) and may vanish from North Sumatra Province soon. Only 210 elephants survive across nine separate ranges in Riau, which in 1985 was considered to have the largest elephant population in Sumatra with over 1,600 individuals.

Simple extrapolations from past population history suggests that Riau's last surviving elephants may soon disappear if the current trend of forest loss continues⁹⁰. A 2009 survey of nine forest blocks in Riau that had elephant herds in 2007 revealed that six herds had gone extinct⁹¹.

Still, Sumatra is thought to have some of the largest populations of Asian elephants outside of India and Sri Lanka. Elaborate dung count surveys in Lampung Province's two national parks, Bukit Barisan Selatan and Way Kambas, produced population estimates of 498 (95% CI=[373, 666]) and 180 (95% CI=[144, 225]) elephants, respectively. But province-wide surveys at the same time also showed that by 2002 elephants had gone locally extinct in nine of 12 elephant ranges recorded in Lampung in the early 1980s⁹².

Main threats

The decline of elephant numbers has been related to forest loss,⁹³ which remains the single biggest threat to Sumatra's elephants. Clear-cutting by the pulp & paper and palm oil industries continues to wipe out remaining elephant forests or fragments them so much that they can no longer maintain viable populations. Encroachment into conservation areas for production of palm oil, rubber, and coffee and other agricultural products is severely threatening even the areas specifically designated for conservation. Most of Sumatra's

23 “extinctions” of local elephant herds happened in areas where large areas of forest were lost or severely fragmented (Map 13). Riau Province lost 63% of its forest between 1985 and 2008/9 (Chapter 6), but its elephant population declined even faster: up to 84% between 1985 and 2007⁹⁴. Further clearance, logging and encroachment of forest will cause further loss and fragmentation of elephant habitat and increase the potential for a significant increase in human-elephant conflict.

Retaliatory killings after human-elephant conflict (HEC) are the other, though closely related, major threat to Sumatran elephants. HEC is widespread throughout Sumatra. Its main cause is the ever-changing and increasing interface between elephant and human utilization zones. More and more people and their crops enter natural elephant habitat and reduce it further and further. But elephants do not simply go away. They begin feeding in the oil palm plantations and crop fields that have replaced their forest. As that conflict of interest over access to land escalates, elephants are poisoned by angry plantation managers and small land holders or removed by local authorities in poorly managed capture or translocation operations that have high mortality rates^{95, 96, 97}.

Conflict rates are highest at the interface, where shrinking and fragmented natural forests were recently replaced by oil palm plantations and agricultural fields, often illegally. Deaths on both sides, destruction of houses, plantations and/or fields are the result. Efforts to solve the issue and chase the elephants back into the natural forest have become less and less effective as the remaining natural forest blocks get smaller and smaller and elephants are forced to leave them again in search of food. By 2008/9, 46% of all elephant population ranges did not have natural forest cover. Areas covered by oil palm or other agriculture are likely to experience high levels of conflict between elephants and humans.

Instead of mitigating HEC using the many tools readily available at the local level, authorities have been responding to conflict reports by translocating unwelcome elephants to ranges in other areas that were already suffering from shrinking habitat and food resources. Many elephants died in the process and some relocated animals tried to move back to their original habitat, causing more conflict along the way. Other elephants were captured and moved to so-called elephant training centers. High mortality due to poor management, capture, training and maintenance standards resulted in the loss of a large number of elephants. But even those who survived were still lost to the wild gene pool. Some of the elephant herds that became locally extinct did so because of such translocations and captures. Between 1984 and 2008, 341 and 227 elephants were recorded to have been captured in Lampung and Riau^{98, 99, 100}, respectively. The actual figures very likely were much higher as elephant deaths during these captures tended to go undocumented in the official reports¹⁰¹.

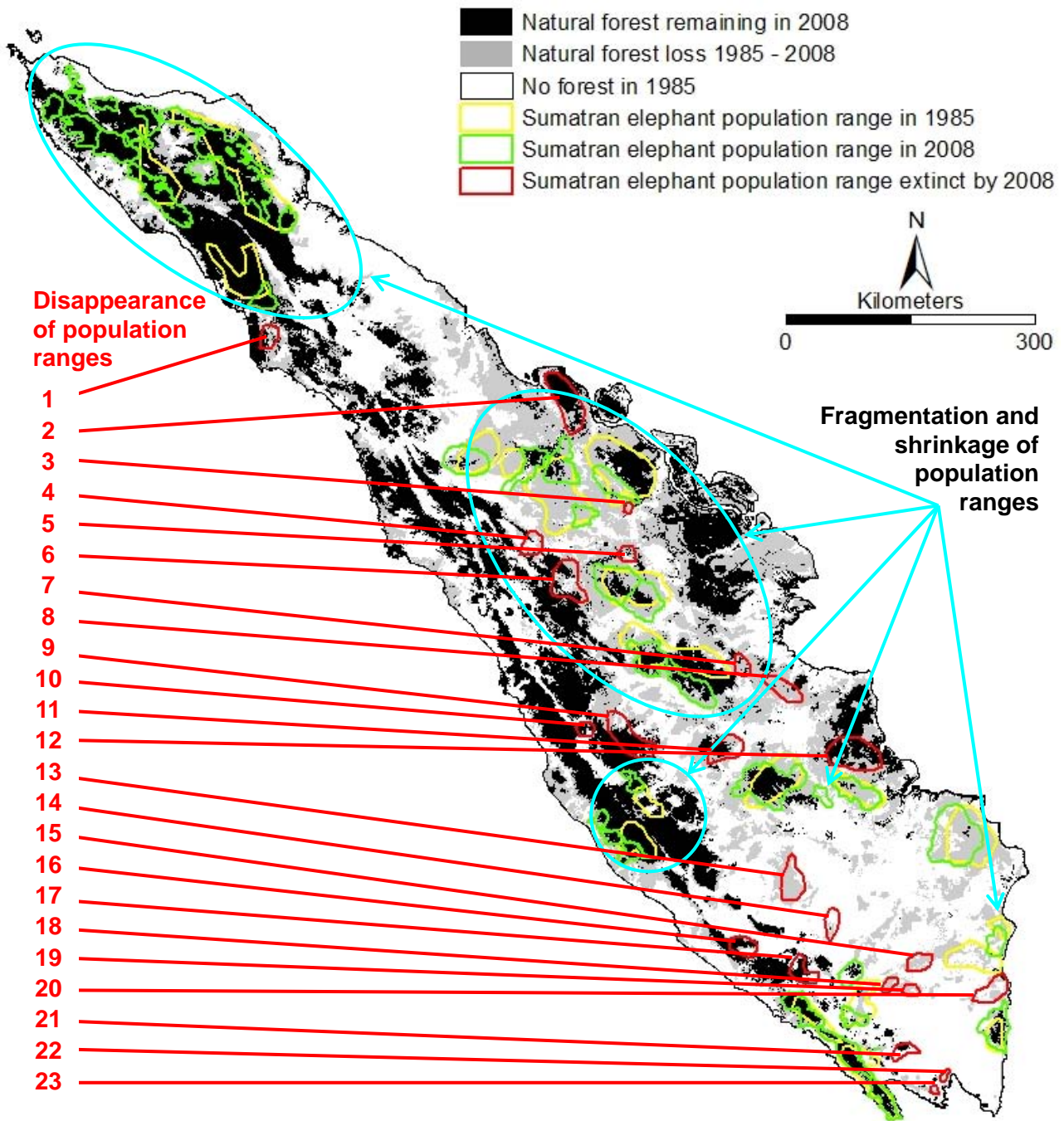
Poaching exclusively for the trade of elephant tusks has been observed. But killing of elephants mostly seems to serve two purposes: conflict resolution and ivory. All male elephants killed in conflict and during captures by the authorities had their tusks removed. The ivory disappeared without a trace.

Survival requirements

An adult elephant eats 100 to 300 kilograms of food and drinks 200 liter of water per day¹⁰². Elephants live in family groups that form larger related groupings known as clans. Clans need large areas of forest with adequate resources (food and water sources) to survive. Elephants will feed on natural vegetation when their home ranges are intact and un-fragmented¹⁰³ but will also use agricultural crops whenever they are accessible or when natural food is inadequate due to loss or fragmentation of forests. As forests disappear, increasing numbers of elephants die in conflict with humans over crop raiding. More than two third of all elephant ranges are outside Conservation or Protection Forest zones today; 46% of all 2007 elephant habitat units were no longer covered by natural forest in 2008/9.

Island, provincial and district land-use planning processes should consider the urgent need of Sumatran elephants for large blocks of connected forest or other natural habitats (Chapter 10) in the designation of urgently needed new conservation and forest restoration areas that would ensure the survival of the country's elephants. Authorities and plantation owners should ensure that plantation and agricultural crops adjoining

forest blocks with elephants are professionally and effectively protected from elephants in search of food to eliminate the need to poison or capture and translocate the animals.



Map 13.—Loss and fragmentation of natural forest cover and the ranges of Sumatran elephant populations between 1985 and 2007/2008. Natural forest in 1985 (grey) and 2008 (black) are shown with 1985 elephant ranges which had disappeared by 2008 (red) and original 1985 elephant ranges (yellow) which had shrunk or become fragmented by 2008 (light blue).

9.2. Sumatran Orangutan (*Pongo abelii*)

2008 IUCN Red List of Threatened Species Category: Critically Endangered¹⁰⁴
CITES: Appendix I¹⁰⁵

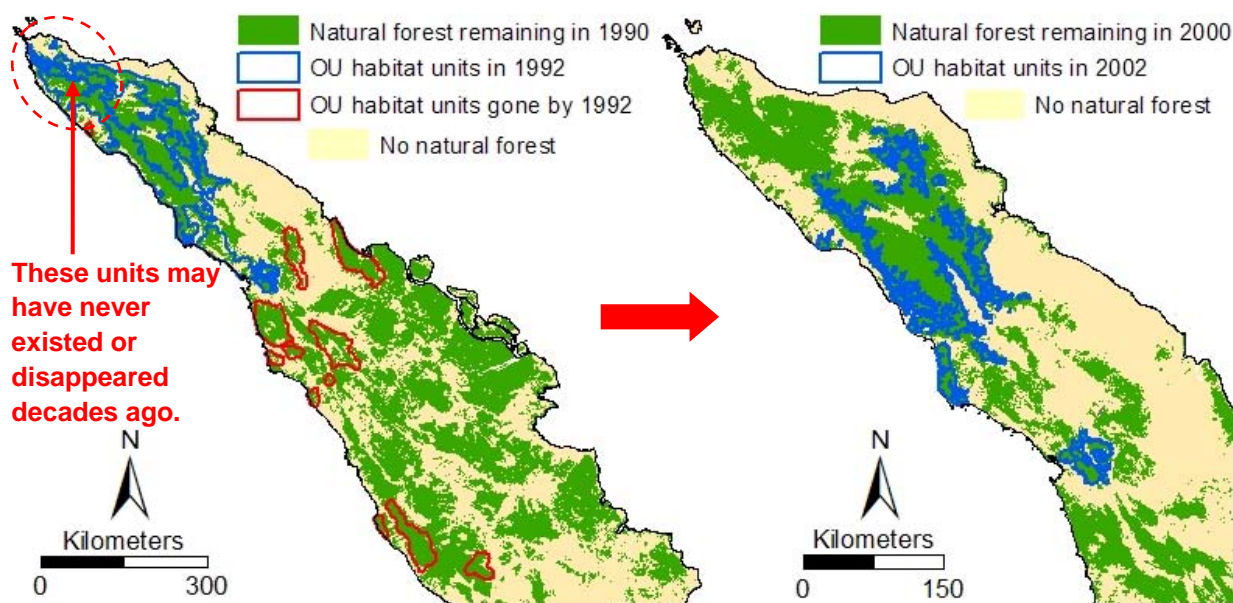
The Sumatran orangutan, endemic to Sumatra, is one of two orangutan species. Its sister species lives on the island of Borneo. The lowest published total population estimate is 6,624¹⁰⁶, indicating an at least 50% decline since 1990s¹⁰⁷. Over the last 75 years, until 2007, the orangutan population is believed to have declined by over 80%¹⁰⁸.

Populations

Until the 1960s: Until at least the mid-1800s, Sumatran orangutans occurred as far south as Jambi and Padang¹⁰⁹. They were reported in parts of West Sumatra Province as recently as the 1960s¹¹⁰. Red boundaries in Map 14a show these old habitat units¹¹¹. There is no reliable total population estimate for this time period.

1990s: By 1992, orangutans only remained in Aceh and North Sumatra (blue boundary, Map 14a)¹¹². Data from before the Aceh conflict are scant and not convincing. Experts had assumed that orangutans had existed in northern Aceh (circled by red hatchet line) simply for lack of a good reason why they wouldn't be. However, it now seems almost certain that they have not been there for decades, if not much longer¹¹³. In 1997, 12,770 orangutans were estimated to live in Sumatra¹¹⁴.

2001-2002: Surveys by Wich *et al.* (2003)¹¹⁵ found no evidence of orangutans south of the areas adjacent to the Batang Toru river (Map 14b). The remaining habitat units had become more fragmented or smaller. 7,501 Sumatran orangutans were estimated in 21 habitat units around 2001 and 2002^{116, 117}.

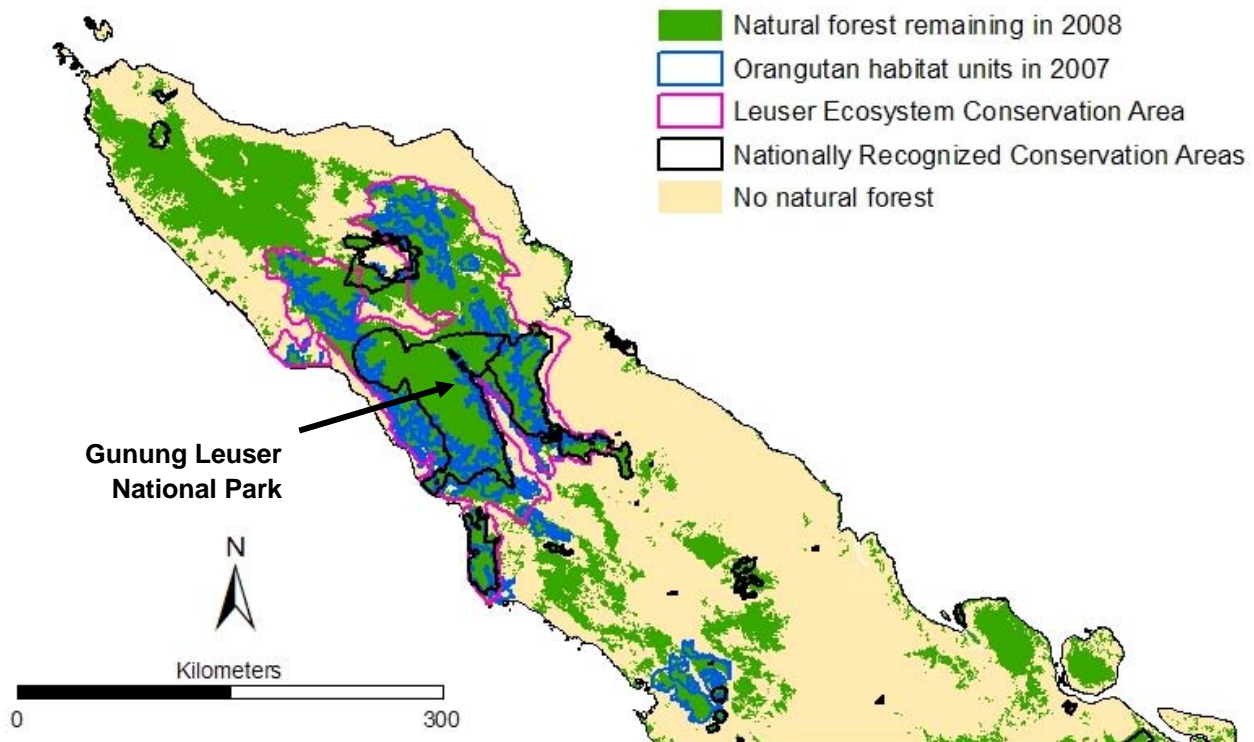


Map 14 a & b.—Natural forest in 1990 and Sumatran orangutan habitat units in 1992 (left map) and natural forest in 2007 and Sumatran orangutan habitat units in 2002 (right map).

2007: The lowest published population estimate for Sumatran orangutans is 6,624 individuals living in 18 habitat units¹¹⁸ (Map 15). The “Leuser Ecosystem” conservation area (purple boundary in the map) is the remaining stronghold for the Sumatran orangutan with 91.7% of all Sumatran orangutans occurring within its boundary¹¹⁹. The 2.6 million hectare conservation area¹²⁰ includes the 1,094,692 hectare Gunung Leuser National Park (large area with black boundary inside the Leuser Ecosystem) with about 25% of all orangutans¹²¹. The three largest populations (with more than 1,000 individuals each) occur in the lowlands of

the Leuser Ecosystem¹²². Another 8.3% of the population is found in the West Batang Toru and East Sarulla forest blocks, in the Tapanuli region of North Sumatra.

In addition to the original wild populations, a new population is being established with the reintroduction of confiscated illegal pets in the Bukit Tigapuluh National Park landscape, straddling the border between Jambi and Riau provinces. The Frankfurt Zoological Society (FZS), in collaboration with Bukit Tigapuluh National Park and BKSDA Jambi, had released 101 orangutans at the border of the park by the end of 2008¹²³.



Map 15.—Orangutan habitat units, natural forest cover in 2007, Leuser Ecosystem Conservation Area (purple boundary), and Gunung Leuser National Park (arrow).

Main threats

Development of oil palm plantations and other agricultural encroachment, roads, illegal and legal logging, transmigration, and slash-and-burn farming continue to lead to orangutan habitat destruction, disturbance and fragmentation¹²⁴. These often lead to human-orangutan conflict. Orangutans raiding fruit crops are often killed. When females carrying infants are targeted, the latter are captured and given into private hands and the illegal pet trade.¹²⁵ The majority of illegal pet orangutans confiscated by the authorities are kept by police and military personnel or local government leaders.

Two major threats to the core range of orangutans are developing today. The Ladia Galaska road network in Aceh will rapidly fragment most of the remaining populations. The post-conflict resumption of activities by logging and palm oil concession-holders will severely disturb and clear large tracts of the remaining lowland forests in Aceh. Clearing of forests results in the local extinction of any resident orangutans. Logging and other roads facilitate access to the forests for poachers and hunters.¹²⁶ The December 2004 tsunami escalated the situation by generating a dramatic increase in the demand for timber and other natural resources¹²⁷.

The introduced orangutan population in Jambi is also in peril. Rather than moving into the relative safety of the steep interior of Bukit Tigapuluh National Park, the released individuals tend to prefer the more level terrain and slightly richer forests surrounding the park. There they have recently come under serious threat from the Asia Pulp & Paper company of the Sinar Mas Group^{128, 129, 130} which is beginning the conversion

of these natural forests for pulp and paper production.

Differently from the very rapid dying of Sumatran elephants, most of the extinctions of Sumatran orangutan habitat units happened over a long period of time prior to 1990. Since then, the landscapes of the remaining orangutan units have not lost much natural forest. In 2008/9, 94% of all 2007 orangutan habitat units were covered by natural forest. But they now have come under threat. Habitat units have become fragmented and shrunk even in Aceh's relatively large contiguous natural forest areas. In 2008, 76% of all 2007 orangutan habitat units were inside Conservation or Protection Forest zones. Most of the orangutan forest outside Conservation Class is inside the Leuser Ecosystem, established by a Presidential Decree, ratified by the Minister of Forestry, implicitly mentioned as a conservation area in the Aceh Governance Law (UU11 2006), in which no development is allowed that conflicts with conservation and in which all land use decisions must be agreed to by the Aceh Government.

Survival requirements

Sumatran orangutans depend on high quality primary lowland forests with little disturbance; their densities may plummet by up to 60% in areas with even selective logging¹³¹. Although timber extraction may, in certain situations, be compatible with orangutan conservation, the total conversion of forest to monoculture plantations is not, and industrial timber and oil palm plantations do not provide viable orangutan habitat¹³². The latter may incite conflict in which orangutans die. Home ranges of female orangutans can be 800 to 1,500 hectares and males may range in excess of 3,000 hectares¹³³.

Island, provincial and district land-use planning processes should consider the urgent need of Sumatran orangutans for large blocks of high-quality, undisturbed forest not intersected by infrastructure like roads in the designation of urgently needed new conservation areas that would ensure the survival of the island's orangutans. Authorities and plantation owners should ensure that plantation and agricultural crops adjoining forest blocks with orangutans are professionally and effectively protected from animals in search of food to eliminate the need to shoot or capture the conflict animals.

9.3. Sumatran Rhinoceros (*Dicerorhinus sumatrensis*)

2008 IUCN Red List of Threatened Species Category: Critically Endangered¹³⁴

CITES: Appendix I¹³⁵

The Sumatran rhinoceros today may be restricted to Sumatra and Borneo. The species also once was widely present in Peninsula Malaysia, however, extremely low rhino track encounter rates recorded in recent years indicate that the Sumatran rhinoceros is probably close to extinction in mainland Asia^{136, 137, 138}. It is one of three extant rhino species in Asia and is the smallest and the most primitive species of all living rhinos¹³⁹. Another rhino species in Indonesia, the Javan rhinoceros (*Rhinoceros sondaicus*), is also critically endangered, surviving in two tiny surviving populations: around 50 individuals on the very western tip of the Indonesian island of Java^{140, 141} and maybe as few as six individuals remaining in Vietnam¹⁴².

The Sumatran rhinoceros is listed as critically endangered on the IUCN Red List due to severe global decline of more than 80% over three generations (generation length is estimated at 20 years) and because its global population size is estimated to number fewer than 200 mature individuals and without effective intervention, the species is expected to continue to decline at least by 25% within one generation¹⁴³. Sumatran rhinoceros in Sumatra is one of three recognized subspecies (*Dicerorhinus sumatrensis sumatrensis*)¹⁴⁴ with the current population estimate of between 145 and 200 individuals¹⁴⁵. Over the last 21 years (one generation), between 1986 and 2007, the population estimate declined by up to 82% (Table 11).

Populations

Before 1986: Van Strien¹⁴⁶ compiled sites of rhino sightings, tracks, killings, captures, wallows in the field and from local reports between 1790 and 1973 and believed Sumatra rhinos originally existed in all provinces of mainland Sumatra (Map 16). However, there was no island-wide estimate of Sumatra's rhino population until 1986. Contemporary literature suggests that population densities of Sumatran rhinos were already low throughout their range by the late 19th century, including their supposed "stronghold" of Sumatra¹⁴⁷, suggesting that typical population density of the species is naturally low (lower, for example, than elephants or wild cattle) and/or that prolonged hunting had already reduced numbers everywhere. The fact that both Javan rhinos and tapirs became extinct throughout much of their former range in Sumatra and Borneo before the dramatic expansion of humans suggests that these large browsers do not naturally live high densities in closed canopy tropical rainforests.

1986: The total number of Sumatran rhinos in Sumatra is estimated between 425 and 800. These estimates are simply educated guesses and hence must be treated with caution. The three most important rhino areas were: Gunung Leuser, Kerinci Seblat and Bukit Barisan Selatan¹⁴⁸ (Table 11).

1991: Until the early 1990's global numbers continued to decline at a rapid rate with estimated losses of 50% or more per decade¹⁴⁹. By 1991, between 420-785 Sumatran rhinoceros are estimated to live on Sumatra¹⁵⁰. The global population is estimated at between 536 and 962 animals¹⁵¹.

1993: Between 215 and 319 Sumatran rhinoceros are estimated for Sumatra¹⁵².

1995: 156 Sumatran rhinoceros are estimated for Sumatra¹⁵³.

1997: The global population of Sumatran rhinoceros is estimated at fewer than 400¹⁵⁴. Between 100 and 250 rhinos are estimated for Sumatra with the largest populations in Gunung Leuser, Bukit Barisan Selatan and Kerinci Seblat¹⁵⁵.

2007: Over the last decade, eight populations of Sumatran rhinoceros in Sumatra have gone extinct (Table 11). Poaching pressure had reduced their population to an estimated 145 to 200 individuals living in Gunung Leuser National Park (60–80), elsewhere in Aceh Province (10–15), Bukit Barisan Selatan National Park (60–80) and Way Kambas National Park (15–25)¹⁵⁶ (ranges shown in blue boundary in Map 16). Although the numbers suggested for Gunung Leuser National Park are between 60 and 80 individuals,

those numbers have not been confirmed by surveys.

Table 11.—Population estimates of wild Sumatran rhinoceros.

Location	Forest Status	Province	Captive Breeding Program 1988-1992 ¹⁵⁷	Rhino number				
				1986 ¹⁵⁸	1991 ¹⁵⁹	1993 ¹⁶⁰	1995 ¹⁶¹	2007 ¹⁶²
Way Kambas	TN	Lampung	No data	No data	No data	3-5	16	15-25
Bukit Barisan Selatan	TN	Lampung	No data	25-60	25-60	25-60	22	60-80
Gunung Patah	HL	South Sumatra	No data	Few	Unknown	10-15	12	Extinct
Bukit Tapan/Silaut (Kerinci Seblat NP)	TN	West Sumatra	No data	No data	No data	5	5	Extinct
Kerinci Seblat NP (Gn Sumbing – Masurai, Sungailpuh/ Gn Seblat, Bt Kayu embun, Ketenong)	TN	Jambi Bengkulu	No data	250-500	250-500	G. Sumbing (40-50), Bt.Kayu Embun (10-15), Ketenong (unknown)	28	Extinct
Around Kerinci Seblat NP(Sungai Ipuh/G. Seblat)	HP		7 captured in S. Ipuh/G/ Seblat			S.Ipuh/G.Seblat (6-7)		
Berbak	TN	Jambi	No data	No data	Perhaps extinct	Present	4	Extinct
Bukit Hitam	HL	Bengkulu	No data	No data	No data	3-5	5	Extinct
Torgamba/Tanjung Medan	HP & oil palm plantation	Riau	8 captured	10-15	Very few	3-5	4	Extinct
Rokan Hilir	HP	Riau	No data	No data	No data	Present	Small	Extinct
Pangarayan/Dalu-dalu	HP	Riau	3 captured	No data	No data	2	No data	Extinct
Gunung Leuser	TN	Aceh	No data	130-200	130-200	90-120	60	60-80
Lesten/Serbojadi	HL, HP	Aceh	No data	Few	15-25	15-25	No data	10-15
Lokop (300 ha)	CA and HP	Aceh		Few		3-5		
G Abong-abong	HL	Aceh		10-25		Present		
Total in Sumatra			18 captured	425-800	420-785	215-319	156	145-200

* Abbreviations: TN: National Park, HL: Protection Forest, HP: Production Forest, CA: Natural Reserve.

Main threats

The three principal threats are habitat encroachment, reduced population viability and poaching¹⁶³. Poaching is primarily driven by the assumed medicinal properties of rhino horns and other body parts¹⁶⁴. Many rhinos were lost to poaching in the early to mid-1990s¹⁶⁵. Though poaching has been brought largely under control from 1997 onwards¹⁶⁶, eight populations went extinct between 1997 and 2007, including a quite large

population in Kerinci Seblat National Park (Table 11).

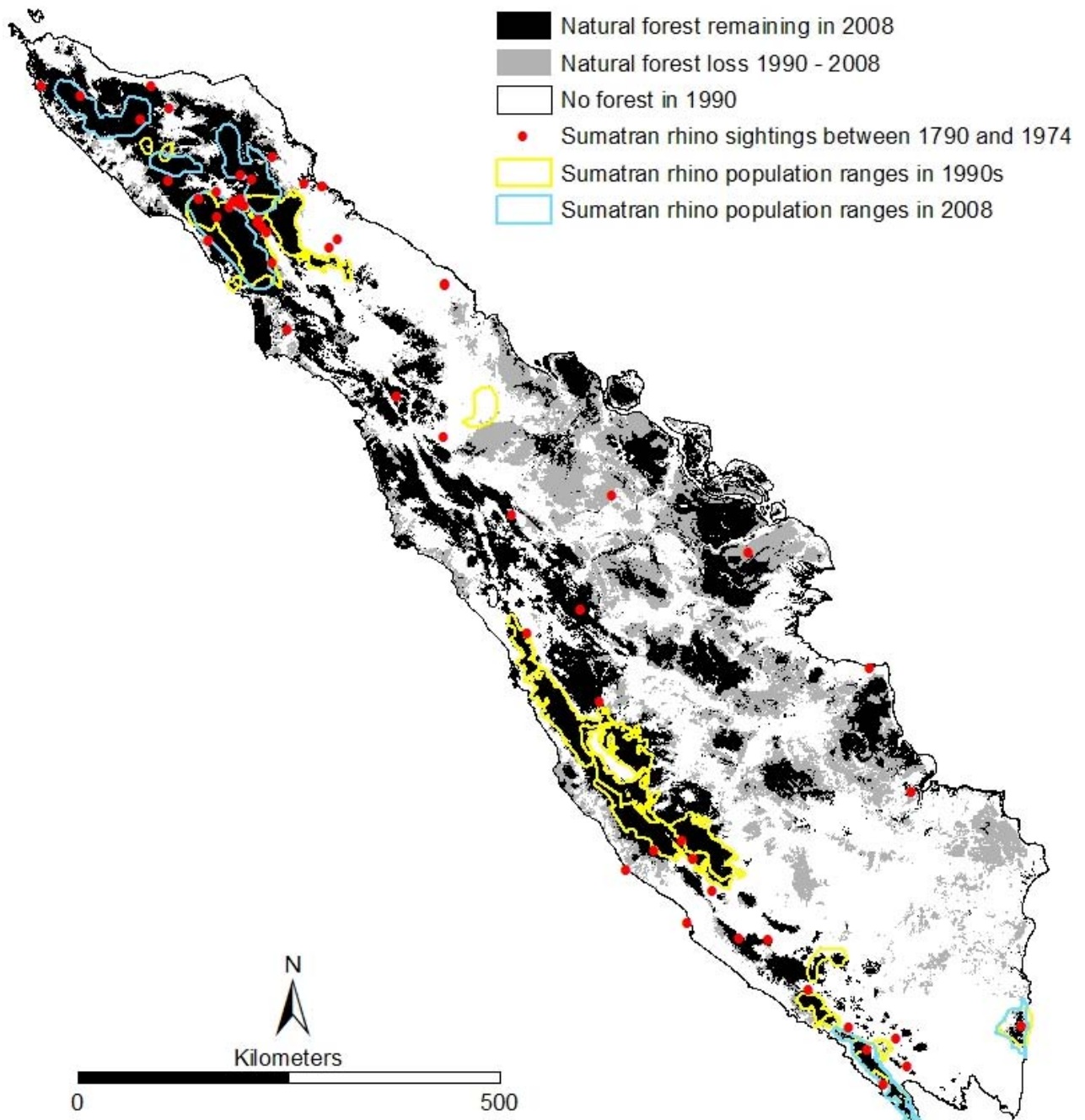
Centuries of over-hunting have reduced this species to a tiny percentage of its former population and range with very small numbers in each locality¹⁶⁷. The species is now so reduced that there are very small numbers in each locality where it still survives, and indications of births are uncommon everywhere¹⁶⁸. However, signs of at least seven calves or juveniles were found during surveys in Way Kambas National Park in 2008 and 2009¹⁶⁹. There is also likely to be a so far speculative but severe risk of inbreeding depression¹⁷⁰. The expansion and reinforcement of anti-poaching programmes is the top priority if this species is to survive¹⁷¹. An extensive international co-operative programme for the conservation of this species is being implemented with *in situ* activities being conducted in Indonesia and Malaysia. In Sumatra, “Rhino Protection Units” were developed in Way Kambas, Bukit Barisan Selatan and Kerinci Seblat National Parks in 1997 as effective anti-poaching teams with law enforcement power. After dramatic declines in population numbers in Gunung Leuser, Bukit Barisan Selatan and Way Kambas National Parks, these populations appear to be slowly expanding in number and range again in recent years, mainly due to intensive anti-poaching measures implemented by Rhino Protection Units¹⁷². Rhino Patrol Units are operating in Bukit Barisan Selatan and Way Kambas National Park. No poaching incident has been reported from there since 2005 when one rhino was shot by poachers in BBSNP.

Habitat loss is now probably the major threat to the survival of Sumatran rhinos and is caused by logging, mining, shifting agriculture and other land uses. Lowland forest habitats and wetlands are particularly threatened since these are the areas most accessible for agricultural development¹⁷³. All Sumatran rhinoceros in Sumatra are now confined within officially protected areas (National Parks or Protection Areas), except a small population in Aceh (10-15 individuals thought to live outside Gunung Leuser National Park). Sometimes rhinos wander into agricultural lands adjacent to the protected areas. In Bukit Barisan Selatan National Park rhinos often go out into the Andatu selective logging concession adjacent to the park, which still has good forest and is of great importance for rhinos.

Survival requirements

Historically, the Sumatran rhino used a variety of habitats ranging from lowland swamp forest to primary rain forest up to an altitude of 1,900 meters¹⁷⁴. Rhinos are typically browsers, feeding on a large number of different species, mostly shrubs and trees. Male and female rhinos both establish territories. There they use wallows and visit salt lick regularly. Rhinos live for a week, a month or considerably longer in an area of 8 to 10 kilometers², then move a considerable distance, but often return to the original locality.¹⁷⁵ This strict regime of visiting fixed sites within their territory makes rhinos very vulnerable to poaching.

Island, provincial and district land-use planning processes cannot directly influence poaching but they can ensure that roads and other infrastructure are not planned near to or even dissecting contiguous forest blocks occupied by rhinos. Such infrastructure improves access by poachers which may wipe out a whole rhino population in a very short time and it effectively reduces the habitat available to rhino as they tend to roam far away from roads. Authorities need to dramatically increase anti-poaching efforts to secure the survival of the few rhinos remaining today.



Map 16.—Loss and fragmentation of natural forest cover between 1990 and 2007, rhino sightings between 1790 and 1973 and the ranges of Sumatran rhino populations between 1990s and 2007. Natural forest in 1990 (grey) and 2007 (black) shown with rhino sightings between 1790 and 1973¹⁷⁶ (red dots), 1990s rhino ranges¹⁷⁷ (yellow boundary) and 2007 ranges¹⁷⁸ (light blue boundary).

9.4. Sumatran Tiger (*Panthera tigris sumatrae*)

*IUCN Red List of Threatened Species Category: Critically Endangered*¹⁷⁹

*CITES: Appendix I*¹⁸⁰

The Sumatran tiger, found only in Sumatra, is one of five extant tiger subspecies recognized by phylogenetic analysis¹⁸¹. Mazak & Groves (2006) consider Sumatran tiger as a distinct species¹⁸². Three (or four if the South China tiger, *P.t.amoyensis*, is included) tiger subspecies are considered extinct in the most recent IUCN Red List assessment¹⁸³. Two subspecies in Indonesia went extinct on the islands of Java and Bali in the 1980's and 1940's, respectively. The Sumatran tiger is classified as critically endangered on the IUCN Red List of Threatened Species, with an effective (breeding) population of likely fewer than 250 mature individuals, suffering from habitat loss and illegal hunting¹⁸⁴. Data on historical and current population size and distribution are limited and have relied on models that use tiger habitat availability and potential tiger carrying capacity within habitat types as indicators.

Populations

1977: 1,000 tigers estimated to be alive in the wild¹⁸⁵.

1992: 500 tigers estimated to be alive in the wild¹⁸⁶.

2007: Research covering most of the main tiger habitat suggests a population size of 441-679 individuals¹⁸⁷. Rather than indicating a possible population increase between 1992 and 2007, these revised estimates reflect an improvement in the assessment methods and availability of better spatial habitat data. Furthermore, at least 250 tigers are estimated from camera trapping studies in eight out of the 18 areas recognized as potential Sumatran tiger habitat¹⁸⁸. However, the method of estimation in these surveys was different from the one used for the 1992 estimate, making direct comparisons difficult. Reliable information on Sumatra tiger distribution is limited and confined to regional level mapping of so-called tiger conservation units (TCUs) that were developed in 1998¹⁸⁹ and revised as tiger conservation landscapes (TCLs) in 2006¹⁹⁰ (Map 17). Sumatra has twelve TCLs, 16% of all TCLs in all range countries. Here we used TCU and TCL locations merely as indicators for tiger presence, with the grading of TCLs from long-term to regional to global indicating increasing likelihood of the presence of a viable population. However, tigers have frequently been reported from many areas outside of the TCLs shown here. It thus appears prudent to apply the precautionary principle and assume tigers to be present throughout the TCUs and Sumatra's forested landscape and beyond.

The whole of Sumatra is currently being surveyed using a scientifically defensible field and statistical methodology that should produce a more specific tiger estimate than is currently available.

Main threats

Sumatran tigers are threatened by loss and fragmentation of natural forest from oil palm and pulp wood plantation development, small-scale agricultural expansion, road development, illegal poaching and trade of tiger parts for domestic as well as international markets and poaching of tiger prey^{191, 192, 193, 194}. An ongoing study investigating habitat use by tigers in a variety of land cover types in Riau¹⁹⁵ revealed that natural forests are the most suitable habitat for tigers¹⁹⁶. Therefore, the loss of natural forest implies a decline of its tiger population. The Ministry of Forestry's "Sumatran tiger conservation strategy and action plan¹⁹⁷," endorsed the delineated Tiger Conservation Landscapes (TCL). But many of the TCLs, especially those in central Sumatra, are under severe threat from rapid planned deforestation (natural forest conversion inside pulp wood concessions) and unplanned deforestation (natural forest encroachment and conversion by people, mainly to plant oil palm). Eleven, 44 and five percent of natural forest remaining in 2000/8/9 in Global, Regional and Long-term Priority TCLs was in existing or proposed HTI concessions and are thus under very severe threat of conversion. Only 55% of all TCU/TCL areas had natural forest cover and around 60% of the

TCU/TCL areas still covered by natural forest were outside conservation areas.

Sumatra's rapid forest conversion has dramatically increased the proximity of humans and tigers, with conflict as an invariable result. With no formal reporting system in place, records of such conflict have only opportunistically been collected across Sumatra. However, conservative estimates from known conflict incidences between 1978 and 1997 arrived at 146 human deaths, 265 tiger deaths and 97 tiger captures¹⁹⁸. Another 40 human deaths were recorded by the Indonesian Department of Forestry between 2000 and 2004¹⁹⁹. In Riau province alone, WWF, Yayasan Program Konservasi Harimau Sumatra and HarimauKita (the Sumatran Tiger Conservation Forum) recorded 235 human-tiger conflict incidences between 1999 and 2007²⁰⁰. Most violent incidents between people and tigers in Riau Province between 1997 and 2009 have occurred near forested areas being cleared by Asia Pulp & Paper (APP) and associated companies, according to an analysis of human-tiger conflict data²⁰¹.

Tigers are severely threatened by poaching for the illegal supply of their body parts to domestic and international markets^{202, 203, 204, 205}. Between 1998 and 2002, at least 51 tigers per year were killed on average, more than 78% for trade and 14% as a result of human-tiger conflict²⁰⁶. Ng and Nemora found the parts of at least 23 tigers for sale in market surveys around the island²⁰⁷. Additionally, though very difficult to assess, tigers are threatened by poaching of their prey, which reduces their food base.

Survival requirements

Tigers require large areas to roam. In Way Kambas National Park, known in Sumatra for its high prey densities, one male's home range was calculated to be 116 square kilometers over a 16-month period²⁰⁸. Yet tigers in areas with lower prey densities may require ranges of 300 square kilometers²⁰⁹. Sumatra's lowland forests support higher tiger densities than its highland forests^{210, 211, 212, 213}. Two factors contributing to the tiger's vulnerability to extinction is its naturally low population density and its relatively low recruitment rate (offspring surviving long enough to join the breeding population) driven by a high rate of first-year infant mortality^{214, 215}. Thus, relatively large areas need to be protected to conserve viable tiger populations with enough individual breeding tigers to survive high poaching levels, epidemics or natural catastrophes²¹⁶. At present many existing protected areas are too small to maintain such populations²¹⁷.

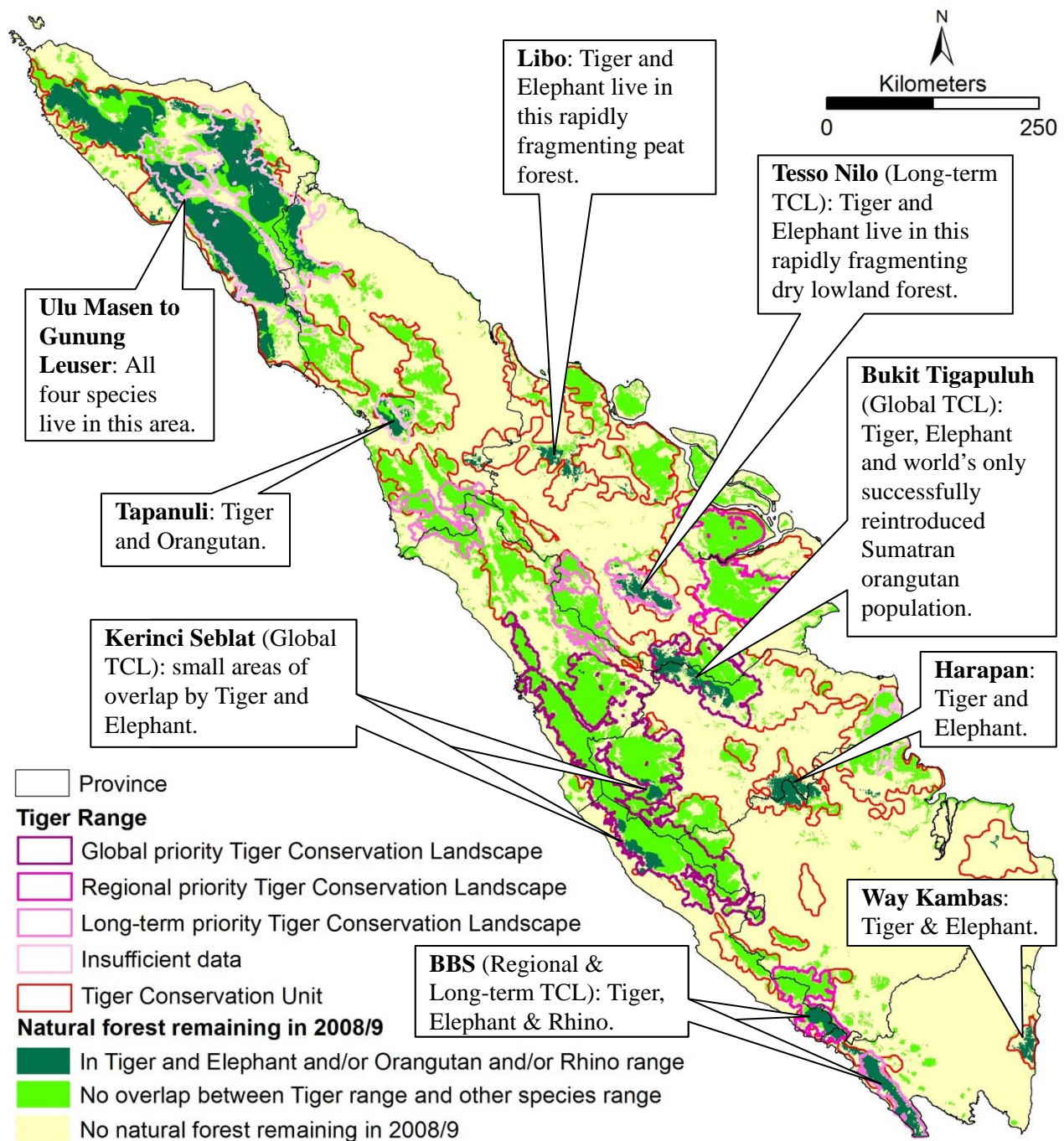
Much of the natural forest inside TCLs is not protected. It is inside of pulpwood concessions, many of which already have permits to clear the forest. And it is inside expired/inactive selective logging concessions (HPH) many of which are targeted by the pulp and paper industry and thus in danger of being rezoned and converted to pulp wood plantations. These threats exist despite the fact that most remaining natural forest in Sumatra is legally protected as "conservation class" or "protection forest" by Republic of Indonesia Government Regulation Number 26 Year 2008 Concerning the National Land Use Plan.

Following Government Regulation Number 26, would offer land use planners the easiest opportunity to address the Sumatran tiger's urgent need for large blocks of protected forest or other natural habitats. National, provincial and district land-use plans could rezone HPHs as Ecosystem Restoration Concessions and design inter-connected new and expanded tiger and carbon stock conservation areas that would ensure the survival of the country's tigers. These new networks could even be based on existing forest conversion licenses according to the Republic of Indonesia's Government Regulation Number 26 Year 2007 on Spatial Plan. Its Article 77 subsection (1) stipulates "as the land use plan is determined, all spatial use that is not aligned to the land use plan should be adjusted to the land use plan." And Article 37 subsection (6) stipulates "Permits for spatial uses that are not appropriate due to an adjustment of the regional land use plan can be revoked by the Government and local government by providing fair compensation". Pulpwood, logging and other concession licenses which allow conversion or timber extraction of natural forest in Sumatra could thus be requested for voluntarily return to Government zoning authorities or even be revoked based on existing legislation.

The Indonesian Ministry of Forestry agrees that the 14 recommendations from the Kathmandu Global

Tiger Workshop 2009 “*Saving wild tigers is our test; if we pass, we get to keep the planet*” (30 October 2009)²¹⁸ are relevant to Indonesia. They emphasize the importance of protection of tigers’ core breeding zones and conservation and management of buffer zones and corridors. Indonesia’s National Workshop on Tiger Conservation re-confirmed Indonesia’s “National Goals for Reversing the Trajectory to [Tiger] Extinction” on 20 January 2010. The Ministry of Forestry’s Tiger Conservation Committee agreed on 23 May 2010 that everything possible should be done to double the tiger populations in the Tiger Conservation Landscapes (TCLs) Gunung Leuser Ulu Masen, Bukit Tiga Puluh, Kerinci Seblat, Bukit Barisan Selatan-Balai Rejang Landscapes which are considered tiger source populations.

Island, provincial and district land-use planning processes should consider the urgent need of Sumatran tigers for large blocks of protected forest or other natural habitats (Chapter 10) in the designation of urgently needed inter-connected new and expanded conservation areas that would ensure the survival of the country’s tigers. Authorities need to dramatically increase anti-poaching efforts to secure the survival of the few tigers remaining today. As an apex species, tigers reflect the health of ecosystems in which they live and on which people depend. There are only very few areas left where the Sumatran tiger coexists with Sumatran elephant, orangutan and rhino: namely, Ulu Masen, Gunung Leuser, Tapanuli, Libo, Tesso Nilo, Bukit Tigapuluh, Kerinci Seblat, Bukit Barisan Selatan National Park and Way Kambas National Park (Map 17). Such areas are globally unique and therefore should be given high priority for conservation, even if they were not classified as TCLs (i.e. Libo, Ulu Masen to Gunung Leuser and Harapan).



Map 17.—Sumatra's natural forest cover in 2008/9 (green areas) with tiger conservation units (TCU, red boundary) and tiger conservation landscapes (TCL) of "Global priority" (black boundary), "Regional priority" (blue boundary), "Long term priority" (light blue boundary) and "Insufficient data" (grey boundary), and their overlap with the ranges of other flagship species in some areas (also see Maps 13 to 16).

10. Prioritizing Conservation Intervention Areas in Sumatra

In Chapters 6 to 9, we discussed some of the High Conservation Values and high carbon values present in Sumatra. For some we presented complex analyses (EFS and flagship species), for others more simple ones (forest carbon and peat carbon). These values need to be preserved. But identifying and prioritizing specific areas for immediate conservation interventions is not easy. Not all values have the same priority for all decision-makers. Presenting potential choices in one or two static maps without being able to give decision-makers a chance to “play” with the data is difficult. To provide readers with at least some options but without overloading our maps with hundreds of polygons in all colors of the rainbow, we reduced the information provided in Chapters 6 to 9 to four simple values:

- A. We chose natural forest cover as indicator for an **above-ground carbon value** and defined it as the whole area covered by natural forest in 2008/9 based on our classification criteria of only areas with original natural (as opposed to anthropogenic) vegetation dominated by trees with greater than 10% canopy cover visually identified on Landsat images as natural forest. Here we did not distinguish the carbon contents of different forest types or of forests in different stages of degradation or regeneration but simply assumed that based on today’s discussions on global climate mitigation these forests have “some” significant existing or future carbon value. Stratifying natural forests by forest types and stages of degradation or regeneration with their likely differences in carbon content would be the next logical step in modeling this value for prioritizing conservation interventions.
- B. We chose peat as indicator for a **below-ground carbon value** and defined it as the whole area delineated as peat swamp by either Wetlands International (2003) or the extent of three eco-floristic sectors associated with peat: fresh water swamps, mixed peat swamps and peat swamps delineated by Laumonier (1997). These two are the most reliable maps available and combined are likely to have captured most peat areas in Sumatra. Here we did not distinguish peat depth or peat soil carbon content but simply assumed that based on today’s discussions on global climate mitigation these peat swamps have “some” significant carbon value. Stratifying peat lands by peat depth and peat composition, likely indicating differences in below ground carbon stocks per hectare, would be the next logical step in modeling this value for prioritizing conservation interventions.
- C. We chose eco-floristic sectors as indicator for a general **floral diversity value** and defined it as the whole area of “critically endangered” and “endangered” EFSs originally defined in 1985. EFSs are the best available representation of Sumatra’s floral – and with it very likely subsets of faunal – diversity. Their current status is the best available indication of extinction risks of this diversity. We assigned this value to areas that are forested today and areas that lost their natural forest since 1985. The latter might provide some indication of how to prioritize reforestation activities if such are considered important. Distinguishing further between EFS with different extinction risk status by selecting either only “critically endangered” or also “endangered” EFS, etc., would be the next logical step in modeling this value for prioritizing conservation interventions.
- D. We chose the most recent known ranges of Sumatra’s four charismatic mega-fauna species as indicator for a **mega-fauna diversity value** and defined it as the sum of all last known habitat ranges of Sumatran elephant, orangutan, rhino and all likely tiger ranges identified by scientists in 1998²¹⁹ and 2006²²⁰. At least two of these flagship species range over very large areas: tigers and elephants. Distinguishing further (1) between the four species, (2) between areas with only one or several of the species, or (3) between the relative importance of specific ranges used by the same species would be the next logical step in modeling this value for prioritizing conservation interventions.

We realize that these values are not all independent of each other. The actual weighting of the values in the end will be up to the individual decision-makers on conservation interventions or climate change mitigations, i.e. is the extinction of the Sumatran rhino worse than the extinction of one of Sumatra’s eco-floristic sectors? Is the extinction of a Sumatran orangutan population easier to avoid when its habitat is natural forest on peat soil and global carbon investors may pay high prices for carbon credits generated by its continuing existence? What are the co-benefits of avoided emissions credits if they save tigers in the

forest whose carbon stocks they pay to maintain?

We mapped the four values across all of Sumatra (Map 18 a & b) and calculated how much of Sumatra’s landmass is covered by all existing combinations of these values (Table 12).

Table 12.—Carbon and biodiversity values in Sumatra’s forested and not forested areas.

Potential priorities for forest protection: areas with natural forest	(ha)	(%)
Forest Carbon + Peat Carbon + Mega-Fauna Diversity + Eco-Floristic Diversity	1,929,380	15.1%
Forest Carbon + Peat Carbon + Mega-Fauna Diversity	19,438	0.2%
Forest Carbon + Peat Carbon + Eco-Floristic Diversity	454,751	3.5%
Forest Carbon + Mega-Fauna Diversity + Eco-Floristic Diversity	1,217,843	9.5%
Forest Carbon + Peat Carbon	51,180	0.4%
Forest Carbon + Mega-Fauna Diversity	8,071,425	63.0%
Forest Carbon + Eco-Floristic Diversity	148,112	1.2%
Forest Carbon	918,868	7.2%
Total area with natural forest	12,810,997	100.0%

Potential priorities for forest restoration: areas no longer with natural forest	(ha)	(%)
Peat Carbon + Mega-Fauna Diversity + Eco-Floristic Diversity	2,690,250	8.7%
Peat Carbon + Mega-Fauna Diversity	142,272	0.5%
Peat Carbon + Eco-Floristic Diversity	2,271,903	7.3%
Mega-Fauna Diversity + Eco-Floristic Diversity	2,194,425	7.1%
Peat Carbon	1,231,120	4.0%
Mega-Fauna Diversity	4,614,109	14.9%
Eco-Floristic Diversity	2,772,385	8.9%
(no value assigned in this model)	15,113,050	48.7%
Total area no longer with natural forest	31,029,513	100.0%

1.9 million hectares (15.1%) of Sumatra covered by natural forest in 2008/9 also had the other values present, while only 0.9 million hectares (7.2%) did not have any additional value beyond forest carbon (Table 12 top). The former were areas with natural forest on peat soil used by at least one flagship species inside an endangered or critically endangered eco-floristic sector. 63% (8.1 million hectares) of natural forest areas in Sumatra had at least one flagship species present, many cases the critically endangered Sumatran tiger.

2.7 million hectares (8.7%) of Sumatra, no longer covered by natural forest in 2008/9, had all the other three values present, while 15.1 million hectares (48.7%) of the deforested areas had none of the values analyzed here present any longer (Table 12 bottom). However, data on “ecosystem services” other than carbon storage/sequestration, comprehensive faunal diversity values other than mega-fauna diversity, or social or cultural values were not used in this analysis. They would very likely highlight the importance of some of the areas currently without value, and may result in a slight shift of priorities for individual forest blocks.

Mapping the four values across all of Sumatra resulted in complex mosaics of polygons shown in two basic color tones: green for forested areas (Map 18a) and brown for no-longer-forested areas (Map 18b). The easiest way to work with this map might be to ask specific questions in regard to the four values: forest carbon, peat carbon, eco-floristic diversity, and mega-fauna diversity. To provide examples, we formulated four questions decision-makers from different stakeholder groups may ask. Each addresses a different subset of combinations of the four values:

1. Question: Where would I invest into natural biomass carbon protection and sequestration in Sumatra to generate the highest possible return from the global carbon markets?

Answer: A (1) deep peat (here just shown as one simple below ground carbon value) covered by (2) dense natural forest (here just shown as one simple above ground carbon value) which is (3) habitat of both charismatic mega-fauna species that use peat lands, tigers and orangutan (here just shown as one simple mega-fauna value).

Map 18a provides a first set of choices for this decision-maker. Areas with the top two colours in the legend show areas with maximum carbon stocks including both forest and peat carbon that would generate so-called co-benefits because they are also mega-fauna habitat. Maps 8, 9, 13 to 17 would provide additional information. Further analysis with our much more detailed full dataset would allow the decision-maker to distinguish the deepest peat and the densest forests with the most charismatic species among the light green areas.

2. Question: Where could I have the biggest impact conserving some of Sumatra's globally outstanding floral diversity?

Answer: A (1) critically endangered or endangered eco-floristic sector (here just shown as one simple eco-floristic diversity value) (2) still covered by natural forest.

Map 18a shows the most appropriate areas for this decision-maker. The first, the third, the fourth and the seventh colour in the legend show endangered and critically endangered EFSs still covered with natural forest. Table 9 and Maps 12 would provide additional information. Further analysis with our full dataset would allow the decision maker to identify the most threatened EFSs with the most intact forest.

3. Question: Where could I protect habitat of one of Sumatra's globally unique charismatic mega-fauna with a conservation concession?

Answer: In (1) the range of at least one of Sumatra's four charismatic species (here just shown as one simple mega-fauna diversity value) covered by (2) natural forest.

Map 18a and Maps 13 to 17 show the most appropriate areas for this decision-maker. The first, the second, the fourth and the sixth colour in the legend show natural forest cover within the range of at least one of Sumatra's four flagship species. Further analysis with our database would allow the decision maker to for example select areas where two or more of the species occur in the best possible forests, which districts in which provinces he would have to inquire about available concessions, and where within the identified range, logging concessions (known locally as HPH) are located.

4. Question: Where would I best restore the habitat of one of Sumatra's globally unique charismatic mega-fauna?

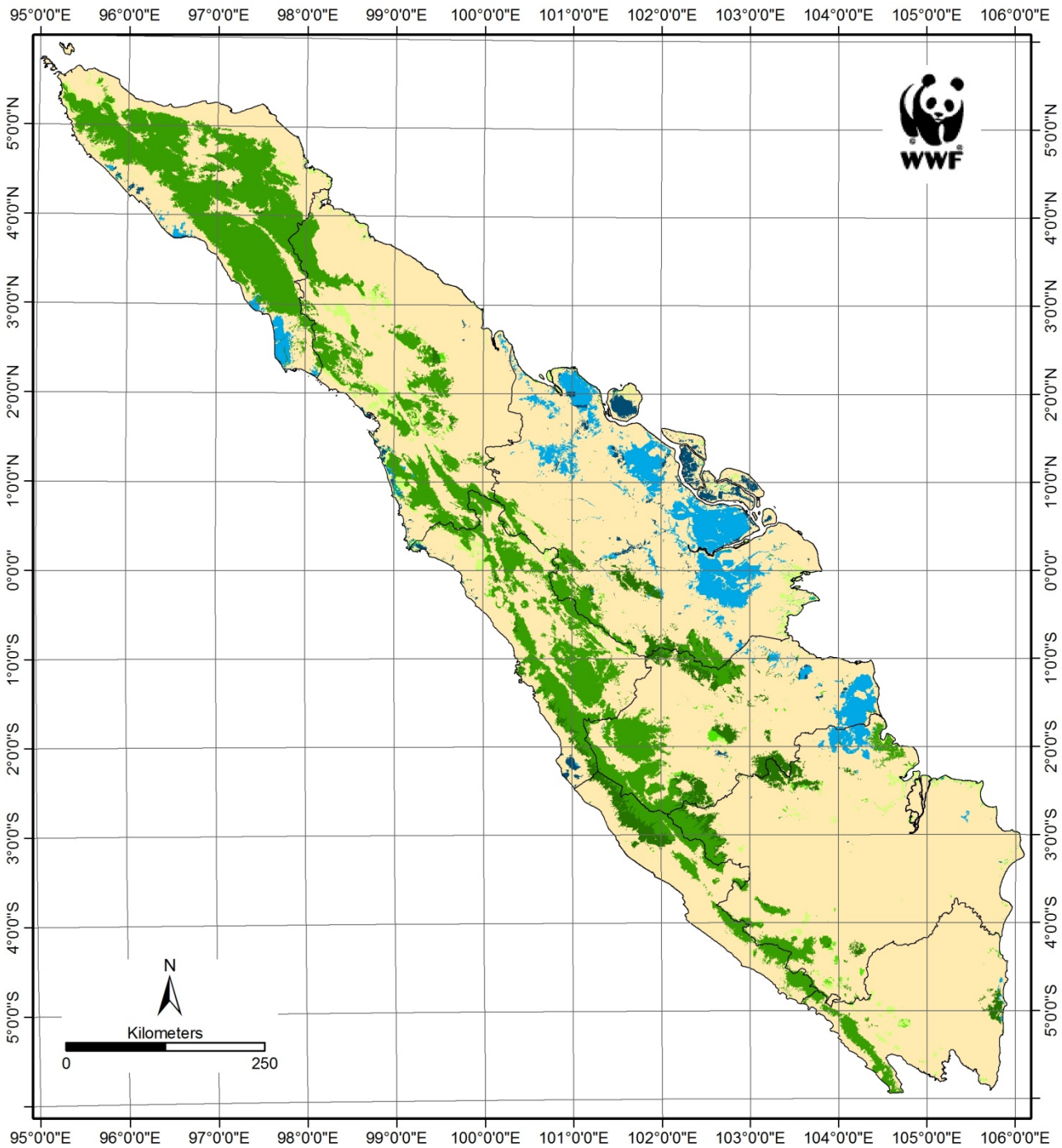
Answer: Any (1) mega-fauna range (2) without forest cover that (3) borders an area with forest would be the best possible solution to expand flagship species habitat.

Map 18b shows the most appropriate areas for this decision-maker, for example the first, the second, the fourth and the sixth colour next to areas in Map 18a that indicates mega-fauna value. Further analysis with our database would allow the decision maker to select areas where two or more of the species use non-forested land outside of forested areas and where such areas border a nationally protected area that increasingly appear as if they will become the last refuges of Sumatra's flagship species.

5. *Question: Where would I best locate new conservation areas to fully protect carbon and biodiversity values?*

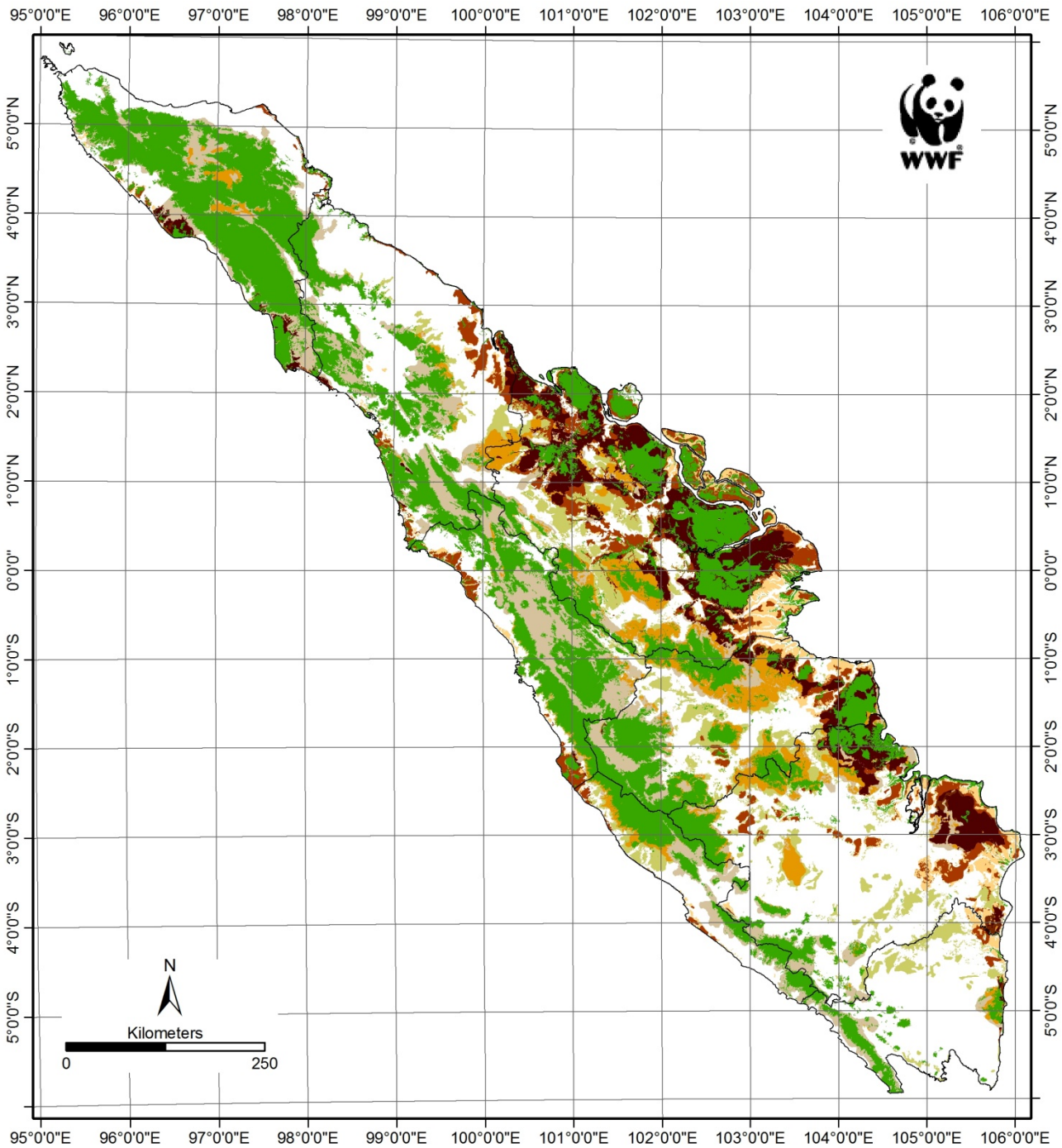
Answer: In (1) any area that has all four values present and that is (2) under-represented in the current system of protected areas.

Map 18c shows that most conservation areas are straddling the steep Bukit Barisan mountain ridge running along the South-west coast of Sumatra (blue hatched) and that the pulp industry instead has been targeting the easy to develop flat central and lately the peat areas along the North-east coast which now have all but disappeared (red hatched). Areas all four conservation values allocated to be cleared for pulp wood plantations are the most threatened and least protected values in Sumatra.



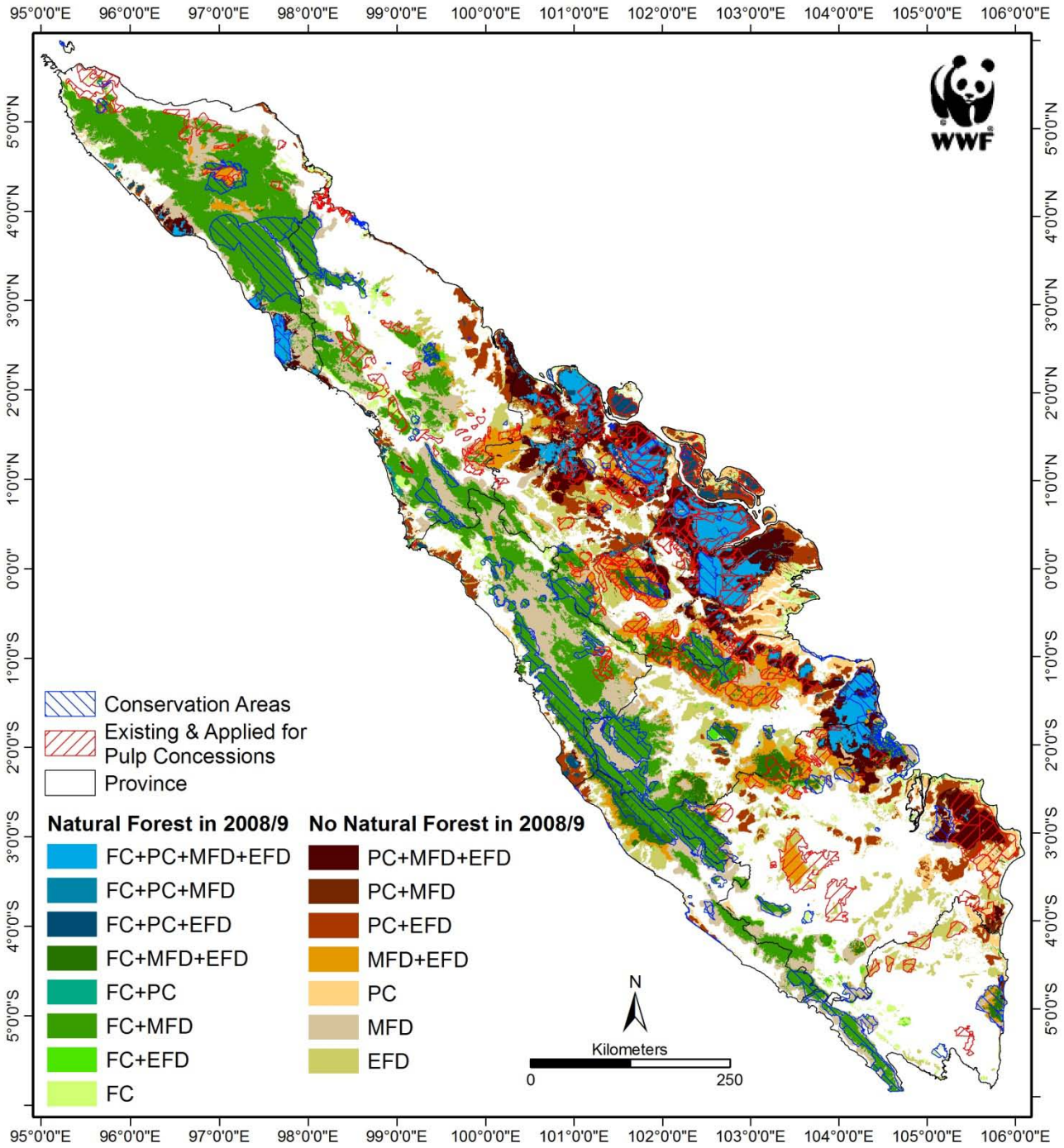
- Province
- Natural Forest 2008/9**
- Forest Carbon+Peat Carbon+Mega-Fauna Diversity+Eco-Floristic Diversity = 1,929,380 ha (15.1%)
- Forest Carbon+Peat Carbon+Mega-Fauna Diversity = 19,438 ha (0.2%)
- Forest Carbon+Peat Carbon+Eco-Floristic Diversity = 454,751 ha (3.5%)
- Forest Carbon+Mega-Fauna Diversity+Eco-Floristic Diversity = 1,217,843 ha (9.5%)
- Forest Carbon+Peat Carbon = 51,180 ha (0.4%)
- Forest Carbon+Mega-Fauna Diversity = 8,071,425 ha (63.0%)
- Forest Carbon+Eco-Floristic Diversity = 148,112 ha (1.2%)
- Forest Carbon = 918,868 ha (7.2%)
- No natural forest in 2008/9 (see Map 18b)

Map 18a.—Natural forest remaining in 2008/9 with and without the other three biodiversity and carbon values: mega-fauna diversity, eco-floristic diversity, and below-ground carbon on the island of Sumatra.



- Province
- Natural forest in 2008/9 (see Map 18a)
- No natural forest in 2008/9**
- Peat Carbon+Mega-Fauna Diversity+Eco-Floristic Diversity = 2,690,250 ha (8.7%)
- Peat Carbon+Mega-Fauna Diversity = 142,272 ha (0.5%)
- Peat Carbon+Eco-Floristic Diversity = 2,271,903 ha (7.3%)
- Mega-Fauna Diversity+Eco-Floristic Diversity = 2,194,425 ha (7.1%)
- Peat Carbon = 1,231,120 ha (4.0%)
- Mega-Fauna Diversity = 4,614,109 ha (14.9%)
- Eco-Floristic Diversity = 2,772,385 ha (8.9%)
- No Value = 15,113,050 ha (48.7%)

Map 18b.—Natural forest in 2008/9 and the three biodiversity and carbon values: mega-fauna diversity, eco-floristic diversity and below-ground carbon in Sumatra’s non-forested areas.



Map 18c.—Sumatra’s four biodiversity and carbon values above-ground (forest) carbon, below-ground (peat) carbon, mega-fauna diversity and eco-floristic diversity relative to current conservation areas (protection) and existing and applied for pulp wood concessions (threat).

11. Prioritizing Potential Development Areas in Sumatra

Clearance of Sumatra’s natural forest has not always been followed by plantation or agricultural development. In many areas timber extraction was the main objective for the clearing. So-called “waste”, “abandoned” or “idle” lands remained. These lands may offer opportunities for industrial or community agricultural development instead of development that clears natural forests and / or drains peat soils.

For this chapter we began identification of such lands in collaboration with SEAMEO Biotrop. We defined “wastelands” as not covered by natural original forest nor secondary re-growth and with no commercial use detectable during visual interpretation of Landsat images taken in 2008 and 2009 (Appendix 1). The identified lands were mostly shrubland (semak/belukar muda), grassland, fernland or overgrowing clear-cut areas.



Shrubs on swampy soil



Shrubs on dry soil (Semak/Belukar Muda)



Grassland/Fernland on swampy soil



Grassland/Fernland on dry soil

We found 4.5 million hectares of potential “wastelands” on Sumatra’s mainland in 2008/9 (Map 19), with provinces differing considerably in the area of potential “wasteland” they have (Table 13). 72% of all wastelands were outside peatlands (3.2 million ha) (Map 19). Potential wastelands outside peatlands were concentrated in South Sumatra (35% total), Aceh (19%), North Sumatra (13%) and Lampung (12%).

Table 13.—Potential “wasteland” available in Sumatran Provinces, ranked by area outside peatlands.

Province	Potential wastelands (ha)	% Total	Outside peatlands (ha)	% Total
South Sumatra	1,774,816	39.8%	1,125,170	35.2%
Aceh	636,479	14.3%	595,422	18.6%
North Sumatra	452,438	10.2%	421,579	13.2%
Lampung	398,365	8.9%	383,090	12.0%
West Sumatra	301,983	6.8%	280,400	8.8%
Bengkulu	163,836	3.7%	162,723	5.1%
Jambi	280,509	6.3%	136,903	4.3%
Riau	448,499	10.1%	93,607	2.9%
TOTAL	4,456,924	100.0%	3,198,892	100.0%

Recommendations

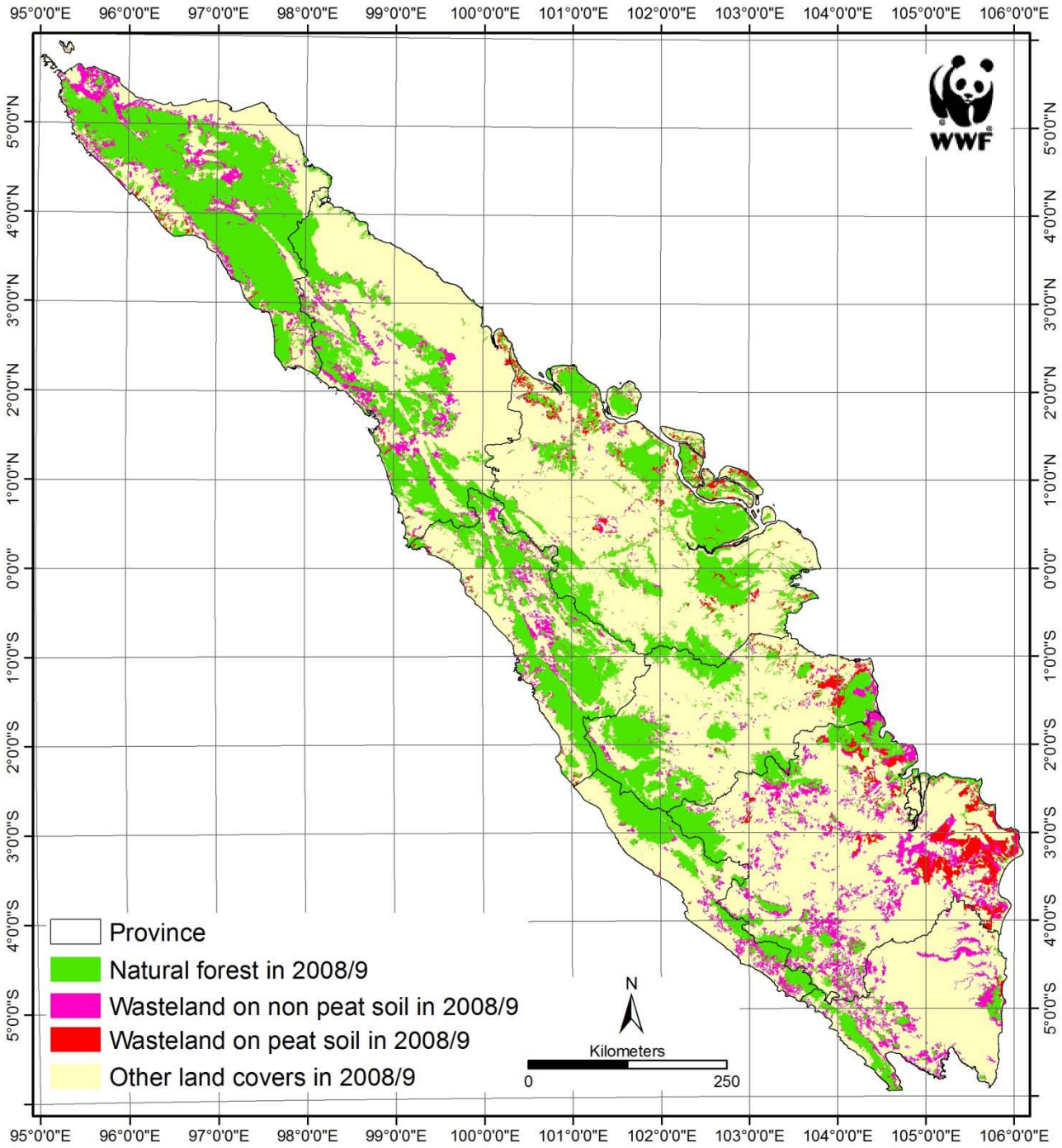
These maps do not identify biodiversity values that these areas with natural vegetation may have, they do not show below ground carbon values or attempt to assign an above ground carbon value to the detected vegetation. These maps also do not indicate any tenure rights or land titles that may exist for these lands. All of these would need to be evaluated before any development by first comparing these areas with maps of High Conservation Values and carbon stocks and then conducting detailed site studies to specify biodiversity and carbon values and especially tenure rights and land titles.

Use of the identified potential “wastelands” for development could be prioritized further based on their location:

1. If located inside oil palm and pulpwood plantation concessions and APL zones these areas should be prioritized for development pending on site analysis.
2. If located inside the Production Forests land use zone, areas outside of pulpwood plantation concessions but inside the Limited Production Forest land use zone, the potential to restore natural forest should be evaluated before such areas are developed.
3. If located inside the ranges of Sumatran tigers, elephants, orangutans or rhinos, the potential to restore natural forest should be evaluated before such areas are developed.
4. If located inside Conservation Area or Protection Forest land use zones, the potential to restore natural forest should be evaluated before any zoning is changed to permit development.
5. If located on peat soil, the potential to stop the drainage of peat soils and restore natural forest should be evaluated before such areas are developed.

Once the prioritization is complete, a three step on-site process would complete the evaluation:

1. on-site identification of High Conservation Values
2. on-site identification of carbon stocks
3. on-site identification of any existing land titles and any tenurial / traditional rights of local people.



Map 19.—Potential “wastelands” and peatland in Sumatra.

12. Appendices

Appendix 1.—Methodology to generate natural forest cover in Sumatra eco-floristic sectors for 1985, 1990, 2000, 2006/7 and 2008/9

All data were processed with ArcGIS and ERDAS softwares.

In order to generate this data set, the authors used the following supporting data:

1. “Sumatra Vegetation Map 1985” (paper maps and raster data). International Map of the Vegetation and of Environmental Conditions: Northern Sumatra; Central Sumatra and Southern Sumatra (Laumonier *et al.*, 1983; 1986 and 1987)²²¹. The map was based on interpretation of Landsat images and aerial photography and considered to represent Sumatra’s vegetation and natural forest cover in 1985.
2. Sumatra forest cover digital map 1990-2000 by WCS (2006)²²², which distinguishes:
 - a. Natural forest
 - b. Non forest
 - c. Water body
 - d. Cloud
3. Aceh & North Sumatra forest cover digital map 2006 (Martin Hardiono 2007)
4. Jambi forest cover digital map 2006 (Warsi 2007)
5. South Sumatra forest cover digital map 2005 (South Sumatra Forest Fire Monitoring Project 2006)
6. Bengkulu forest cover digital map 2003 (Forest Inventory Monitoring Project 2003)
3-6 distinguish only:
 - a. Natural forest
 - b. Non forest
7. Riau Forest and Land Cover database 1990, 2000 and 2007 (WWF 2007), which distinguish:
 - a. Natural forest (14 sub-classes)
 - b. Non forest (34 sub-classes)
 - c. Water body
 - d. Cloud or no information

Satellite Images:

1. Multi-resolution Seamless Image Database (MrSID) of Landsat for all Sumatra 1990
2. MrSID of Landsat for all Sumatra 2000
3. Landsat data for all Sumatra 2006 – 2007 (list in Table 14)
4. Landsat data for all Sumatra 2008 – 2009 (list in Table 14).

Other supporting data:

1. Coastline and administrative data from Bakosutranal
2. Coastline, administrative, river and road from Baplan, Departement of Forestry

Step 1. Vector data of the Sumatra Vegetation Map 1985 was created as follows:

- Vector data (1:1,000,000) was digitized from both original three separate paper maps and raster data (based on ONC US map).
- The three sets of vector data were then matched and re-georeferenced together, based on the Administration Boundary Map (1:100,000, Bakosurtanal 2006) and Forestry Baseline Map (1:100,000, Baplan 2006) using coastline, rivers and lakes as references.
- The two overlapping areas of three separate vector data had to be then re-interpreted and re-delineated as follows:
 - Original 0-500m elevation class in North and South Sumatra was split into two classes of 0-150m and 150-500m to match the same two classes which were present in Riau and Jambi provinces in Central Sumatra.
 - Mismatches of rivers and eco-floristic zone boundaries were corrected.
- Original data of the Sumatra Vegetation Map had a scale of 1:1,000,000. For processing, overlaying and analysis with forest cover data of 1990, 2000 and 2007, which are based on Landsat images

(1:100,000), we needed to re-interpret and re-georeference the vector data to be close to 1:100,000 scale.

Step 2. Sumatra natural forest cover digital map 1990-2000 by WCS (2006) were updated as follows:

- The original WCS data were corrected and reinterpreted by using MrSID Landsat basic data 1990 and 2000.
- It was then re-matched and re-georeferenced using the Administration Boundary Map (1:100,000, Bakosurtanal 2006) and Forestry Baseline Map (1:100,000, Baplan 2006) using coastline, rivers and lakes as references.
- All polygons with area below 50 hectares were eliminated. This is because, in theory, the minimum mapping unit (MPU) for Landsat is 50 ha.
- Based on expert knowledge of the team, some WCS “natural forest” areas that should have been classified as rubber forest in Jambi and several re-growth areas, were re-classified as “non forest”.

Step 3. New natural forest cover map of Sumatra for 2006/7 was created as follows:

- 40 scenes of Landsat images for 2006 and 2007 to cover the mainland of Sumatra were manually interpreted. The method used for interpretation follows techniques recommended by King²²³.
- This was improved using Riau Forest & Land Cover Database (WWF 2007) and enriched by other data listed above.
- This was also then corrected using 1990-2000 as base data to remove anomalies (i.e. no forest area in 2000 becoming forested in 2007) and keep the consistency between the data for 1990, 2000 and 2006/7.

Step 4. New natural forest cover map of Sumatra for 2008/9 was created as follows:

- 27 scenes of Landsat images for 2008 and 2009 to cover the mainland of Sumatra were manually interpreted.
- All the Landsat images were geo-referenced using forest cover map 2007 as a basis for rectification
- Natural forest cover 2007 data was overlaid on 2008/2009 Landsat images and delineated manually all the forest cover change since 2007 to become non forest in 2008-2009.
- This was also then corrected using 1990-2007 as base data to remove anomalies and keep the consistency.

Step 5. Final step

Natural forest cover 1985, 1990, 2000, 2006/7 and 2008/9 data were corrected to remove anomalies and keep consistency, to make sure cases such as natural forest in 2008/9 did not exist in 1985.

Table 14.—List of Landsat images used to generate natural forest cover 2006/7 and 2008/9.

PATH	ROW	2006 - 2007	2008 - 2009	PATH	ROW	2006 - 2007	2008 - 2009
		DATE	DATE			DATE	DATE
P123	R062	-	14-May-08	P126	R061	13-Oct-06	24-Sep-08
P123	R063	25-Mar-07	15-Apr-09	P126	R062	23-Apr-07	19-May-08
P123	R064	5-Aug-06	1-Jul-08	P127	R058	3-Jul-07	No data
P124	R061	20-Aug-06	6-Apr-09	P127	R059	3-Jul-07	14-Aug-08
P124	R062	29-Sep-06	28-Oct-08	P127	R059	1-Aug-06	-
P124	R063	16-May-06	24-Jul-08	P127	R060	3-Jul-07	18-May-08
P124	R064	29-Sep-06	24-Jul-08	P127	R060	16-Jul-06	-
P125	R060	16-Apr-07	8-Feb-09	P127	R061	26-Sep-06	11-Jun-08
P125	R060	3-Aug-06	-	P128	R058	23-May-07	18-Apr-09
P125	R061	27-Jun-07	31-Jul-08	P128	R059	28-Jan-06	18-Apr-09
P125	R061	6-Oct-06	-	P128	R060	28-Mar-07	17-May-08
P125	R062	26-Jul-06	17-Sep-08	P129	R057	27-Jan-06	8-May-08
P125	R063	28-Sep-06	28-Mar-09	P129	R058	6-Jul-06	30-Jul-09
P126	R059	7-Apr-07	30-Jan-09	P129	R059	27-Jan-06	8-Mar-09
P126	R059	10-Feb-07	-	P130	R056	14-Aug-06	No data
P126	R059	26-Aug-06	-	P130	R057	9-Oct-06	7-Nov-08
P126	R060	1-May-07	22-Jul-08	P130	R058	26-Mar-07	31-Mar-09
P126	R060	23-Apr-07	-	P131	R056	8-Oct-06	10-Aug-08
P126	R060	14-Nov-06	-	P131	R057	4-Jul-06	19-May-09

13. References

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