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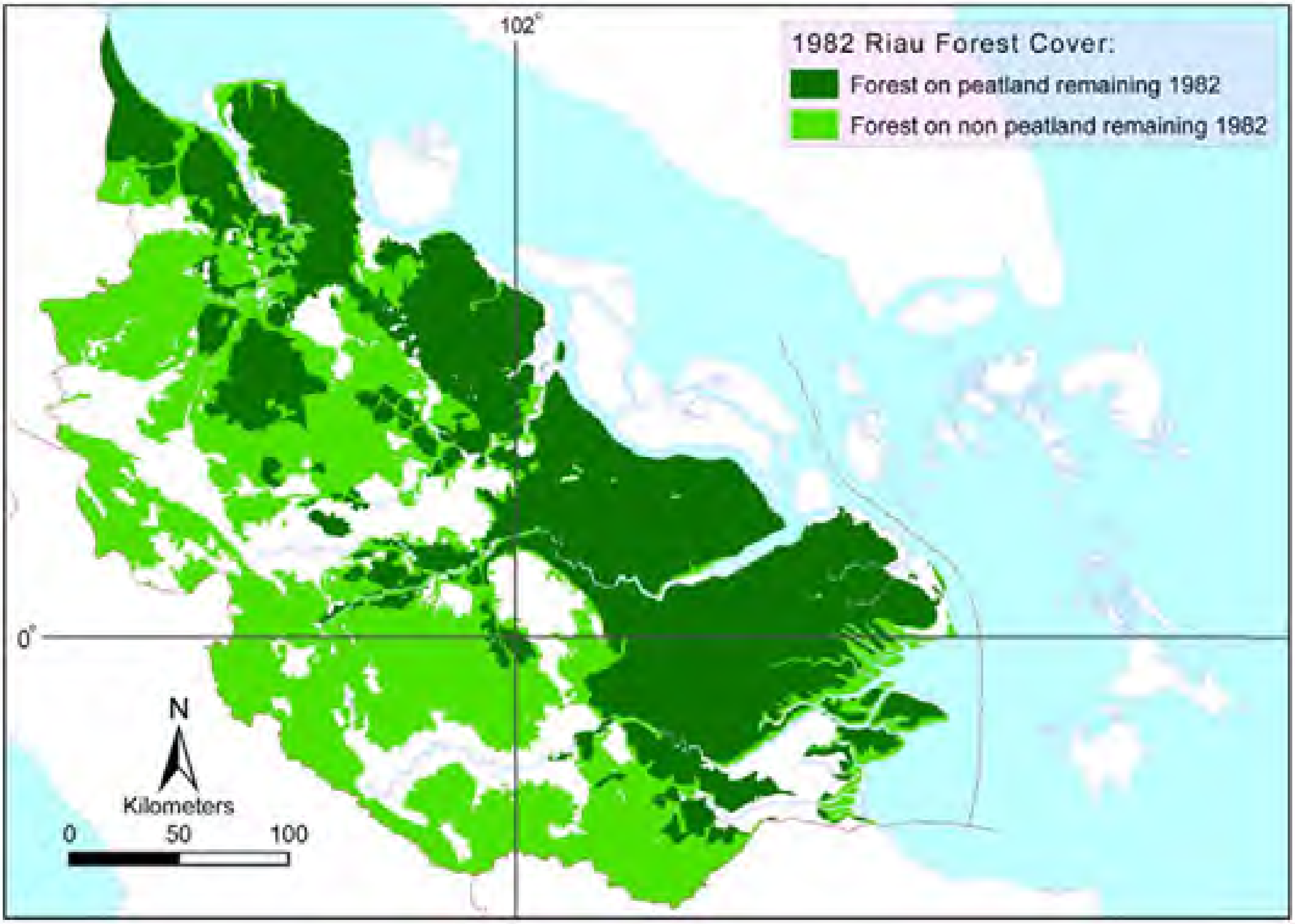
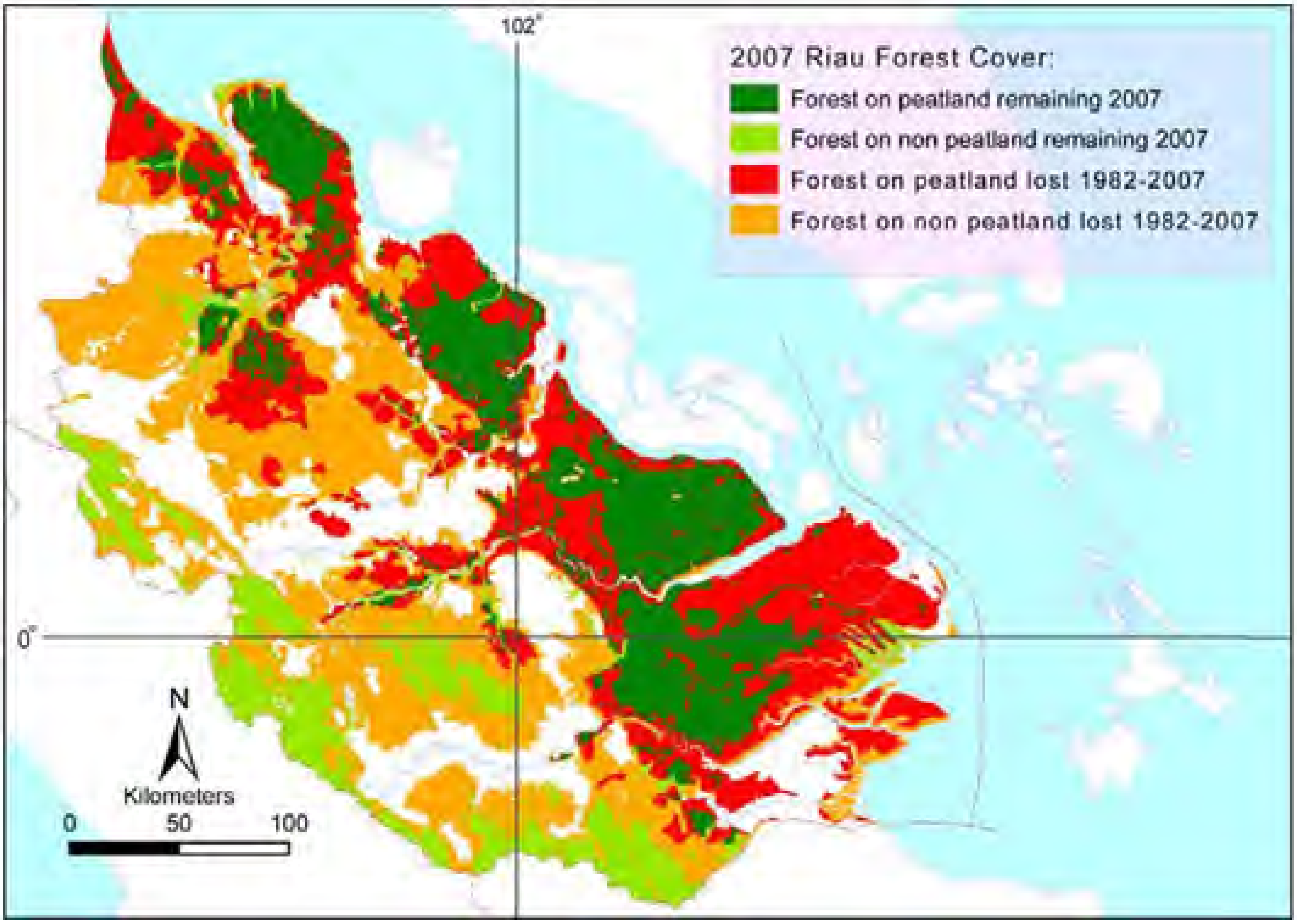
Deforestation, Forest Degradation, Biodiversity Loss and CO_2 Emissions in Riau, Sumatra, Indonesia

One Indonesian Province's Forest and Peat Soil Carbon Loss over a Quarter Century and its Plans for the Future



102°
1982 Riau Forest Cover:
Forest on peatland remaining 1982
Forest on non peatland remaining 1982
0°
N
Kilometers
0 50 100



102°
2007 Riau Forest Cover:
Forest on peatland remaining 2007
Forest on non peatland remaining 2007
Forest on peatland lost 1982-2007
Forest on non peatland lost 1982-2007
0°
N
Kilometers
0 50 100

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Content

1. Executive Summary

Riau Province, in central Sumatra, is covered by vast peatlands estimated to hold Indonesia's largest store of carbon. Riau's remaining forests are home to the endangered Sumatran tiger and elephant. Found nowhere else on Earth, their populations have been declining rapidly across the island of Sumatra.

This report documents pulp wood- and palm oil-driven deforestation and degradation of natural forests and shows how that has caused the decomposition and burning of carbon-rich soil in Riau's vast and deep peatlands. This has resulted in globally significant CO_2 emissions and the much-reported trans-boundary haze across the Malacca Straits. And it has threatened the local extinction of Sumatran elephants and tigers, which have been disappearing faster even than their forests in Riau, largely due to an increase in human-wildlife conflict as animals are driven from the disappearing forest.

The study analyzes deforestation and forest degradation over the last quarter century, between 1982 and 2007. It identifies drivers of deforestation by mapping the land covers that replaced the natural forests. The term "forest" in this report always refers to natural forests and not any industrial and agricultural plantations or other land covers which replace them.

Forest cover in Riau declined by 65 percent over the past 25 years. Deforestation was largely driven by industrial plantation companies despite the fact that large areas of cleared forest remain unused. Riau has almost 900,000 hectares of "waste" lands where plantations could potentially be developed without cutting more natural forest. The study estimates historical and future CO_2 emissions related to deforestation, degradation of forests, degradation of peat soils and burning (the deliberate use of fire in land clearing and "runaway" fires).

Two scenarios for deforestation until the year 2015 were modeled. Looking to the future, the "business as usual" scenario suggests that Riau's natural forest cover would decline to 6% by 2015, from 27% today. The second scenario, assuming full implementation of Riau's draft provincial land use plan, suggests that mainland natural forest cover would decline to 15% by 2015. Of the new deforestation, 84% would happen on peat soil. The deforestation would be driven by the pulp & paper industry (74% of all deforestation). Assuming that all natural forest inside an area zoned for plantation would be converted, by 2015 industrial acacia plantations would have replaced 36% (1.9 million hectares) and oil palm plantations 27% (1.4 million hectares) of all the forest lost since 1982. Open is how much, if any, natural forest would be kept standing inside the plantations.

CO_2 emissions caused by deforestation, forest degradation, peat decomposition and peat fires were estimated based on remote sensing analysis. Average annual CO_2 emissions in Riau between 1990 and 2007 were 0.22 Gt, equaling 79% of Indonesia's total annual emissions from the energy sector in 2004. This estimate may severely over- or underestimate the actual emissions due to the fact that for many processes detailed data on carbon stocks and carbon emissions (stock decrease) were not available. However, considering all possible errors and uncertainties we believe the results indicate at least the order of magnitude of the emissions correctly.

During the 2007 UN Framework Convention on Climate Change Conference of Parties in Bali (COP 13), the parties confirmed the urgent need to take further action to reduce emissions from deforestation and forest degradation and adopted a work program. That program will focus on assessing changes of forest cover and associated greenhouse gas emissions, demonstrating reductions of emissions from deforestation and estimating the emission reductions from deforestation. Financial schemes for trading carbon of "avoided deforestation" will be developed and international compensation funds will be established. This could provide a good future for Indonesia's forest industry, provided solid policies are issued to encourage the commercialization of environmental services, such as avoiding deforestation, water and soil protection and biodiversity conservation. If the profits from marketing environmental services or carbon credits are comparable to those of marketing the timber, more forest would likely be protected by concession holders. This might be the case with Riau's carbon-rich peatland forests and soil underneath. The potential value of trading the protected carbon stocks of these forests may be comparable or even better to other, conventional uses of natural forests.

Key Findings on Deforestation and Forest Degradation

- During the last 25 years, Riau has lost more than 4 million hectares (ha) of forest (65%). Forest cover declined from 78% in 1982 to 27% today. Deforestation between 2005 and 2006 was 286,146 ha, an 11% loss in just one year.

- Of the forest cover lost in the last 25 years, 29% was cleared for industrial oil palm plantations, 24% was cleared for industrial pulpwood plantations, and 17% became so-called "waste" land (land that was deforested but not replaced by any crop cover).

- Two "events" affecting Riau's pulp & paper industry appear to have caused a slowdown in the deforestation rate: the industry's debt default in the early 2000s and a massive police investigation into illegal logging in 2007, which is still ongoing.

- In the study's Tesso Nilo-Bukit Tigapuluh–Kampar Landscape, covering 55% of the province, 90% of the total deforestation was due to clearing of natural forest in still good condition (canopy cover of more than 40%). 96% of the pulp plantations and 85% of the palm oil plantations created there replaced such natural forest.

- Nationally controlled protected areas such as national parks, wildlife sanctuaries, and game reserves were relatively effective in maintaining forest cover, while local and provincial protected areas (Kawasan Lindung) were not.

Key Findings on Biodiversity

- In the last quarter century, Sumatran elephant population estimates in Riau declined by up to 84%, from an estimated 1067-1617 in 1984 to possibly as few as 210 individuals in 2007. If the trend continues and the two largest remaining elephant forests – Tesso Nilo and ex-logging concessions near Bukit Tigapuluh National Park – are not protected, Riau's wild elephant population will no longer be viable and will face extinction.

- Estimates of Riau's Sumatran tiger population declined by 70%, from 640 in 1982 to 192 in 2007, due to habitat fragmentation. Unless the last remaining patches of tiger habitat are connected by wildlife corridors, Riau will not have a viable tiger population.

Key Findings on Fires

- Between 1997 and 2007, more than 72,000 active fires (hotspots) were recorded in Riau by NOAA AVHRR and MODIS satellite sensors. 31% of Riau burnt at least once, 12% burnt more than once. The recurrent fires in particular are a severe threat to rainforest ecosystems because they impede forest regeneration and eventually convert forest ecosystems into grasslands.

- There is a clear link between fire and deforestation.

- Most fires occur in forests with medium to very open canopy closure.

- Only 8% of nationally controlled protected areas were affected by fire, probably because of their comparatively good canopy cover.

Key Findings on Carbon Dioxide Emissions (CO_2)

- Between 1990 and 2007, estimated total emissions in Riau reached 3.66 gigatons (Gt) CO_2, including emissions from deforestation, forest degradation and decomposition and burning of peat -- contributing to Indonesia's ranking as one of the world's biggest emitters of carbon. The total emissions from 17 years exceed the annual total CO_2 emissions of the European Union for 2005 (including emissions/removals from LULUCF: Land Use, Land-Use Change and Forestry). Carbon sequestration by acacia and oil palm plantations that replaced the forest was 0.24 Gt CO_2.

- The average annual CO_2 emissions from deforestation, forest degradation, peat decomposition and peat fires in Riau between 1990 and 2007 was 0.22 Gt, equal to 58% of Australia's total CO_2 annual emissions (including emissions/removals from LULUCF, in 2005), 39% that of the United Kingdom, higher than that of the Netherlands (122%) and 79% of Indonesia's total annual emissions from the energy sector in 2004.

- Between 1990 and 2007, Riau alone produced more CO_2 per year than the fourth-largest industrial nation, Germany, saved to achieve its Kyoto target.

- Were Riau's draft provincial land use plan implemented as is, an additional 0.49 Gt of CO_2 would be released by 2015 due to deforestation alone. If "business as usual" continues, double that amount would be released. Peat degradation and burning are not included in these projections.

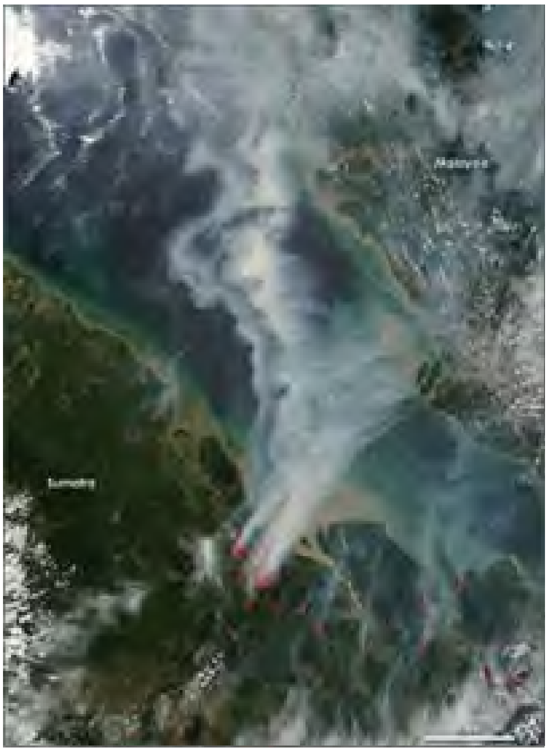
- The average annual emissions from deforestation, forest degradation, peat decomposition and peat fires in Riau between 1990 and 2007 was equivalent to 24% of the collective annual greenhouse gas (GHG) emissions reduction Kyoto target by the Annex I countries in the first commitment period of 2008-2012.

- Global consumption of palm oil and paper has been driving Riau's deforestation; it appears to also drive climate change. Reducing CO_2 emissions would be far more effective if investments were allocated to the avoidance of deforestation.

- Establishment of a mechanism for "Reducing Emissions from Deforestation and Forest Degradation" (REDD), combined with permitting the building of plantations only on "waste" land would undeniably improve the world's anthropogenic carbon emission balance.

2. Introduction

Riau Province in central Sumatra, Indonesia, hosts some of the most biodiverse ecosystems on Earth and unique species such as the critically endangered Sumatran tigers and endangered Sumatran elephants. Comparative studies found Riau's Tesso Nilo dry lowland forest to have the highest vascular plant diversity among 1,800 tropical forest survey plots studied on all continents[1], and higher diversities than other Sumatran and Indonesian forests[2]. In mapping out its priority conservation regions across the world, WWF included dry lowland and peatland forests in Riau as the *Sumatran Islands Lowland and Montane Forests*[3] and *Sundaland Rivers and Swamps*[4] of its Global 200 priority ecoregions. WWF has been working in Riau since 1999, trying to protect Sumatran elephants and tigers and their habitats, especially the tropical natural forests inside the Tesso Nilo–Bukit Tigapuluh–Kampar Conservation Landscape[5] (Equator and 102°E), comprising about 55% of Riau's mainland.



Thick smoke plumes over Riau near North Sumatra moving to Malaysia, as recorded by the Moderate Resolution Imaging Spectroradiometer in 2005 (MODIS) © NASA 2005

These species and their tropical forest habitats have been under very serious threat because of rapid large-scale deforestation. But the problem of deforestation in Riau is not only about the loss of biodiversity. Recently, the global significance of greenhouse gas emissions caused by deforestation, forest degradation and peat decomposition and burning in Indonesia -- especially in Riau -- has been generating increased attention. Both natural forests and peat soils are important long-term, or even permanent, stores of carbon on Earth, with peat soils able to store 30 times more carbon than the tropical forests above them[6]. However, the stability of the peat soil and the long-term storage of its carbon depend on the health of the natural forests covering them. Forest and peat soil fires are the most dramatic visible symptoms of rapid CO_2 emissions from these carbon stores – and the root cause of these emissions is deforestation.

WWF[i] has been monitoring the status of elephants, tigers, and natural forests, the threats to them and the drivers responsible for deforestation and forest degradation in Riau through remote sensing and field surveys, sometimes in close collaboration with two local NGO networks, Jikalahari[ii] and Walhi[iii] Riau, through the joint "Eyes on the Forest" project (www.eyesontheforest.or.id). Current and historical forest cover changes were then analyzed in detail and related to zoning processes.

Besides unraveling the alarming relationship between plantation development and deforestation, biodiversity loss and CO_2 emissions in Riau, this report aims to provide site-specific input for an Indonesian REDD[iv] pilot or a REDD-like voluntary project, supporting the actual definition process with a case study on land use dynamics in one Sumatran province over the past quarter century. The authors hope that REDD for Indonesia and voluntary investors might be able to provide the necessary incentives to stop further deforestation and forest degradation in this and other provinces and thus reduce the province's contribution to climate change, reduce the health and economic consequences of vast annual fires, maintain the forests' biodiversity treasures, and keep Sumatran elephants and tigers alive.

[i] www.wwf.or.id
[ii] www.jikalahari.org
[iii] www.walhi.or.id
[iv] REDD: Reducing Emissions from Deforestation and Forest Degradation

This report will:

- Detail deforestation and forest degradation in Riau over the last quarter century (between 1982 and 2007), identify the drivers of deforestation, and project deforestation until 2015 based on two scenarios: "business as usual" and "implementation of Riau's May 2007 draft land use plan."
- Describe loss of biodiversity due to deforestation and forest degradation and project future loss.
- Estimate CO_2 emissions from deforestation and forest degradation, peat decomposition and burning over the last quarter century and project future CO_2 emissions from deforestation based on two scenarios.

3. Acknowledgements

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4. Background

4.1 Deforestation and CO_2 Emissions

About 20% of the world's greenhouse gas (GHG) emissions are caused by deforestation globally, often in the most biodiverse regions of the world, such as Indonesia and Brazil, which together account for 54% of these emissions[7]. If current rates of deforestation in Indonesia remained the same through 2012, the emissions from this deforestation would equal nearly 40% of the annual emission reductions targets set for Annex I countries in the Kyoto Protocol for its first commitment period[8].

Indonesia's LULUCF (Land Use, Land-Use Change and Forestry) emissions in 2000 were estimated to be 2,563 Mt of CO_2[9], 34% of the global LULUCF emission[10]; most of this was the result of deforestation and forest degradation[9]. In addition, a recent preliminary study estimated peat decomposition and burning in Indonesia to have caused ca. 2,000 Mt CO_2e/year[11], much of that ultimately triggered by deforestation. These two sources of CO_2 emissions, combined with GHG emissions from energy, agriculture and waste (together 451 MtCO_2e[9]), contributed to Indonesia's total GHG emissions reaching ca. 5,000 MtCO_2e/year (Figure 1). This almost pars with the annual GHG emission of China (5,017 MtCO_2e). Only the USA emitted more GHG (6,005 MtCO_2e) [9].

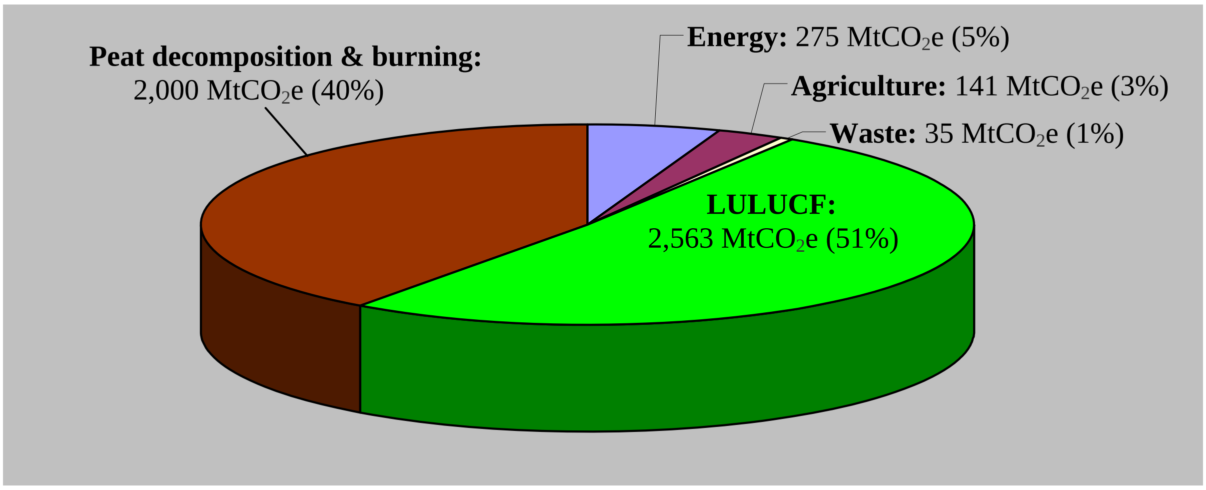
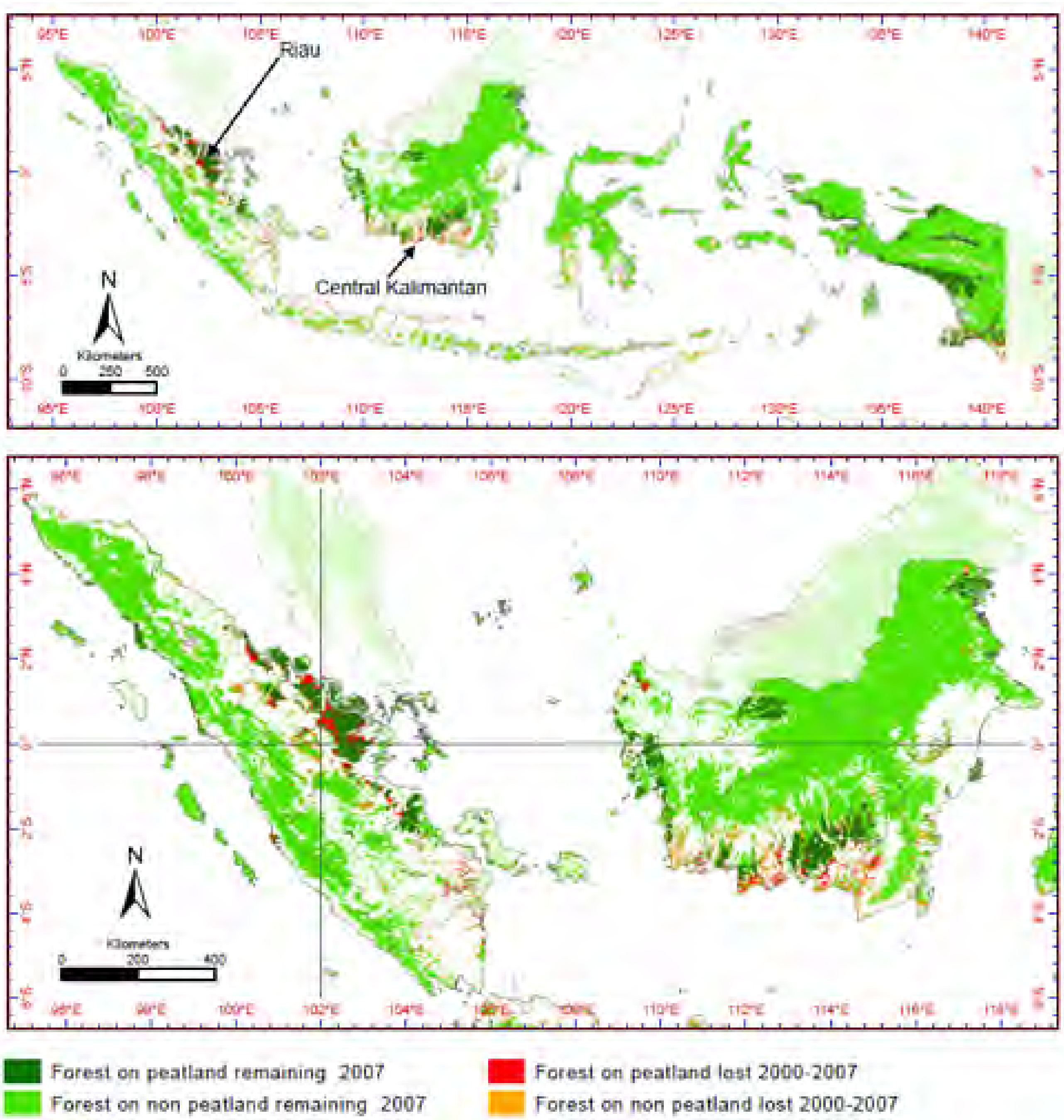


Figure 1.—*The source of greenhouse gas emissions in Indonesia. (Data quoted: energy emission in 2004, agriculture emission in 2005, waste emission in 2005, LULUCF emission in 2000 [9,11])*

In this global and national context, the province of Riau, Sumatra, is key for any decision-making on a REDD mechanism for Indonesia for three main reasons:

1. In Indonesia, the province of Riau has had one of the highest deforestation rates in recent years (Map 1 a & b) and a majority of that recent deforestation has occurred on the province's fragile carbon-rich peat soil. Riau thus contributed significantly to Indonesia's GHG emissions through LULUCF and peat emissions.
2. Riau leads Southeast Asia in terms of total peat soil volume and the carbon it harbors. Indonesia has the fourth-largest area of peatland in the world, ranging from 30 to 45 million hectares, which is approximately 10-12% of the global peatland resource[1213]. Riau has the second-largest area of peat in Indonesia, 4 million ha[14]. Riau's peat soils – sometimes over 10 meters deep – are estimated to store the largest amount of carbon in Indonesia: 14.6 gigatons (ca. 43% of all peat carbon is estimated to be stored in Sumatra, Kalimantan and Papua [14]). Riau (still) has Indonesia's second-largest area of peatland forest after Papua, with some of the remaining large contiguous peatland forest blocks located on top of very deep peat (Map 1 a & b). They are under immediate threat of deforestation, in which case the province would continue to contribute greatly to Indonesia's GHG emissions.

3. Deforestation in Riau today is largely driven by industrial plantation companies. Any deforestation avoided through a potential REDD mechanism may have implications elsewhere in Indonesia or the world as the companies would look for other areas to source wood and build plantations required by their business plans. Development of an effective REDD mechanism will need to address "corporate carbon leakage."



Map 1 a & b.—*Deforestation in Indonesia 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 June 2007. Map 1b is an enlargement with Indonesia's islands of Sumatra and Borneo. Maps were provided by SarVision and are based on a REDD monitoring system developed by SarVision - Wageningen University in collaboration with the Indonesian Ministry of Forestry using MODIS/SPOT Vegetation satellite images with a 250-1000 m resolution. SarVision updates this map every three months.*

4.2 Past and Future of Deforestation in Riau

Deforestation and forest degradation in Riau have been driven by various parties using destructive logging and forest clearance – both illegal and legal – for development of settlements, infrastructure, agriculture, etc. But no other type of deforestation matches the speed and finality of forest conversion by the rapidly expanding pulp & paper and palm oil industries. Between 1982 and 2007, these two industries replaced ca. 2 million hectares of natural forest in Riau.

A local saying goes that Riau is blessed by oil: below and above the ground. Crude oil exploration began in the 1930s in Riau's coastal peatlands. Palm oil exploration began 50 years later on a big scale, starting the province's forest conversion boom that covered Riau with more oil palm concessions than any other province in Indonesia[15]. Over the last decade, however, the palm oil industry saw the rise of a serious competitor in Riau: the pulp & paper industry. Since 1990, deforestation for acacia plantation development has been catching up with deforestation for oil palm plantation development, finally overtaking it in 2000, at least in WWF's Tesso Nilo–Bukit Tigapuluh–Kampar Conservation Landscape, covering 55% of Riau.

Log yard with wood waiting to be pulped at APP mill in Riau. © WWF Indonesia.

Timber from Riau's rain forests – home to some of the highest plant diversity found on Earth – docked at APP pulp mill. © WWF Indonesia.

Two of the world's largest pulp mills, each with an annual capacity of more than 2 million tons, are operated in Riau by Asia Pulp & Paper (APP) and Asia Pacific Resources International Holdings Limited (APRIL). Together, the two companies produce more than two-thirds of Indonesia's pulp[16] and today may "own" the concession rights to ca. 25% of the 8.3 million-hectare Riau mainland. No other Indonesian province has so many pulpwood concessions[17]. Wherever natural forests are cleared to make way for acacia or oil palm plantations, most of the harvested wood goes to one of the two pulp mills. Despite the fact that they have been in business for many years, both mills continue to rely to a large extent on fiber originating from illegal[18] or legal-but-destructive large-scale natural forest clearance. WWF estimated that about 170,000 ha of natural forests were cleared to feed Riau's two pulp mills in 2005[19] alone. This number accounts for about 80% of the total deforestation detected on satellite images between 2004 and 2005.

The pressure of the pulp & paper industry on Indonesia's and Riau's natural forests is going to increase. The Government of Indonesia set mid- and long-term targets calling for 5 and 9 million hectares of (mostly pulpwood) plantations to be established by 2009 and 2014, respectively. In 2004, the country had 4.07 million hectares of pulpwood concessions[20], but according to the Ministry of Forestry, only 1.5 million hectares had actually been planted with pulpwood monocultures[21]. In 2004, the Ministry of Forestry requested pulpwood concession holders to accelerate their pulpwood plantation development and finish all their forest clearing by the end of 2009[22]. At the same time, Government regulation allowed the establishment of pulpwood plantations only on barren lands, consisting of barren land, grasslands or bush (so-called “waste” lands)[v].

4.3 What is at Stake?

Was it really “waste” lands where the pulpwood industry was planting its acacia plantations? If so, are there enough “waste” lands to meet the national pulpwood plantation development targets? If not, is Riau ready for more deforestation? How many more forests can it lose, and at what price for the world’s climate? Where will Riau’s tigers and elephants go? Who will miss out on the pharmaceutical treasures Riau’s forests may still hold, forests that are some of the most diverse on Earth and that remain largely unexplored?

Large area of dense peatland forest scheduled to be cleared in Kampar Peninsula, Riau. © WWF Indonesia

Riau’s Tesso Nilo forest is a microcosm of the processes driving deforestation and species extinction throughout the province. In 1985, Tesso Nilo’s contiguous forest cover stretched across almost half a million hectares that were divided into many selective logging concessions (known as HPH). Over-logging and the subsequent collapse of the selective logging industry led to many of the HPH concessions being rezoned. Logging licenses were replaced first by oil palm and then increasingly by pulpwood concession licenses, under which many natural forests with still-dense canopies were converted to plantations. Today, only about 110,000 hectare of natural forest remains contiguous in Tesso Nilo. Large logging corridors built by the pulp & paper industry and endless logging roads allowed more than 2,500 families to encroach the forest and clear vast stretches. “Real estate” dealers sold lots in the forest they did not own. Existing laws protecting these forests were not enforced.

The Tesso Nilo forest was the best remaining habitat for the endangered Sumatran elephant when WWF-Indonesia came to Riau in 1999 to find ways to protect the province’s elephants from extinction. Already, forest loss had led to a reduction of the herd from an estimated 1067-1617 individuals in 1984[23] to about 700 in 1999[24]. Yet despite all efforts, WWF estimated that only about 210 elephants remained in Riau in 2007[25].

[v] A new Government Regulation, issued in January 2007, allows timber plantation be built on unproductive forest.

Oil palm plantations and their management are one of the root causes of elephant deaths associated with human-elephant conflicts. Elephants like to feed on oil palm trees, farmers and companies do not like to see their crops destroyed and conflict results; elephants die and people die. The more natural forests are fragmented and the longer the interface between natural forest and invading oil palm plantations becomes, the more conflict escalates. WWF found evidence of more than 200 elephants that died or "disappeared" during or after conflict-related official government captures of "problem elephants" between 2000 and 2006[26]. But conflict is not the only elephant killer in Riau; poachers kill too. Logging corridors provide ever-better access for encroachers and illegal loggers to clear previously inaccessible natural forest. These forests are initially full of wildlife driven here by the continuous forest conversions elsewhere. Opportunities to poach are plentiful. Today, only two forests in Riau may still be large enough to keep elephants from going extinct here: Tesso Nilo and the gentle slopes of the Bukit Tigapuluh forest block. Both are highly threatened by conversion.

The critically endangered Sumatran tigers suffer a fate similar to the elephants. With many of their forests gone, some go to hunt pigs near oil palm or other plantations. Sometimes they encounter workers who may get injured or killed. They are pursued relentlessly, captured to remove the threat, killed to trade their skin, bones and other body parts. A team of international tiger scientists classified Bukit Tigapuluh forest block as a global priority tiger conservation area, Riau's Kampar and Kerumutan peat lands as regionally significant areas, and Tesso Nilo and Rimbang Baling as long-term priorities[27]. Without them, Riau's tigers may be doomed. All these forests are highly threatened by conversion.

After 2000, forest conversion began focusing on Riau's peatlands. Long, deep canals dissect all of Riau's peat bogs, draining the soil with canals sometimes more than a meter deep until the loggers, legal and illegal, can go in to cut the trees and float out the logs. The peat subsides and the dried-out soil becomes Riau's number one source of fires. The fires blanket central Sumatra and neighboring Singapore and Malaysia with haze for weeks without end in many years and accelerate the release of untold tons of CO_2. Peat fires also have major impacts on human livelihoods as they appear to drive poverty, which is now up to four times more severe in Indonesian peatlands than in the country's other lowland areas. The fires also cause increased illnesses, with about 30% of all young children in peatlands in Indonesia having respiratory diseases and growth inhibition as a result of peat smoke[28].

Wood for pulp production barged on drainage canals, next to yet another block of peatland forest waiting to be cleared for acacia plantation development. © WWF Indonesia.

4.4 What is in the Future?

At stake are local and regional economies, tigers and elephants, treasures of biodiversity, the human communities (including traditional and indigenous peoples) who inhabit the peat landscapes, secure water supplies and coastal protection, and our global climate. How can they be protected from the relentless exploits of natural forests? How can their values become a variable in the economic formulas utilized when forest conversion licenses and agreements are given to industrial plantation actors?

One of the principal issues at the 2007 UNFCCC Conference of Parties (COP 13) was the political framework for the policy process for "Reducing emissions from deforestation in developing countries"

(REDD). Parties confirmed the urgent need to take further action to reduce emissions from deforestation and forest degradation and adopted a work program for further methodological work. That program will focus on assessments of changes in forest cover and associated greenhouse gas emissions, methods to demonstrate reductions of emissions from deforestation and the estimation of the amount of emission reductions from deforestation. Parties agreed that REDD is an important component of a future climate change regime beyond 2012, in both: mitigation and adaptation. A financial scheme for trading carbon of “avoided deforestation” will be developed; international compensation funds will be established.

Currently, the 1st period of Kyoto Protocol only recognizes reforestation and afforestation as mechanisms to mitigate climate change. Can the Indonesian government commit to REDD for Indonesia to avoid deforestation and forest degradation throughout the country and reduce CO_2 emissions? Can REDD put the “right value” on natural forests for the services they provide so it becomes more profitable to protect than to clear them?

5. Study Areas

Our deforestation, fire and CO_2 emissions study focused on the ca. 8.3 million-hectare mainland of the province of Riau in central Sumatra, Indonesia, along the island's northeastern coastline, near the city of Singapore across the Straits of Malacca (Equator and 102°E). More-detailed forest degradation and forest replacement analysis focused on WWF-Indonesia Riau Programme's 4.5 million-hectare Tesso Nilo-Bukit Tigapuluh–Kampar Conservation Landscape (TNBTK Landscape), covering ca. 55% of Riau's mainland (Map 2).

Map 2.—*Tesso Nilo–Bukit Tigapuluh–Kampar Conservation Landscape within Riau within Sumatra within Southeast Asia.*

Tiger surveys in Riau's peatlands.
© WWF- Indonesia/Sunarto

6. REDD – Deforestation

We analyzed deforestation in Riau over the last quarter century, between 1982 and 2007. We determined drivers of deforestation, identifying which land covers had replaced the natural forest that had been cleared and which land use zones has seen such changes. Finally, we predicted what deforestation may occur between 2007 and 2015 based on two scenarios: "business as usual" and "implementation of the draft land use plan" currently before the Riau Parliament.

In Chapter 10, we relate deforestation to carbon loss, estimating past and predicting future CO_2 emissions.

6.1 Deforestation of Riau 1982 - 2007

We defined "forest" as area with original natural forest with a crown cover of more than 10% (following FAO's definition of forest)[29]. We did not include plantations such as acacia and oil palm plantations under the term "forest." We also did not include forest re-growth in "forest." We mapped "forest-non forest" cover for the years 1982[vi], 1988[vii], 1996[viii], 2000[ix], 2002, 2004, 2005, 2006, and 2007 for Riau's 8.3 million-hectare mainland. We distinguished forests on peat versus non peat soils based on a delineation of peatland in Riau by Wetlands International[30] (Appendix 1).

Between 1982 and 2007, Riau's mainland lost 65% (4,166,381 ha) of its original forest cover, reducing its forest cover from 6,420,499 ha (78% of mainland area) to 2,254,118 ha (27%). Riau's peat soil lost 57% (1,831,193 ha) of its forests; its non peat soil lost 73% (2,335,189 ha). (Figure 2, Map 3 a-j). Deforestation of non peat soil is slowing, while deforestation of peat soil is accelerating (Figure 2).

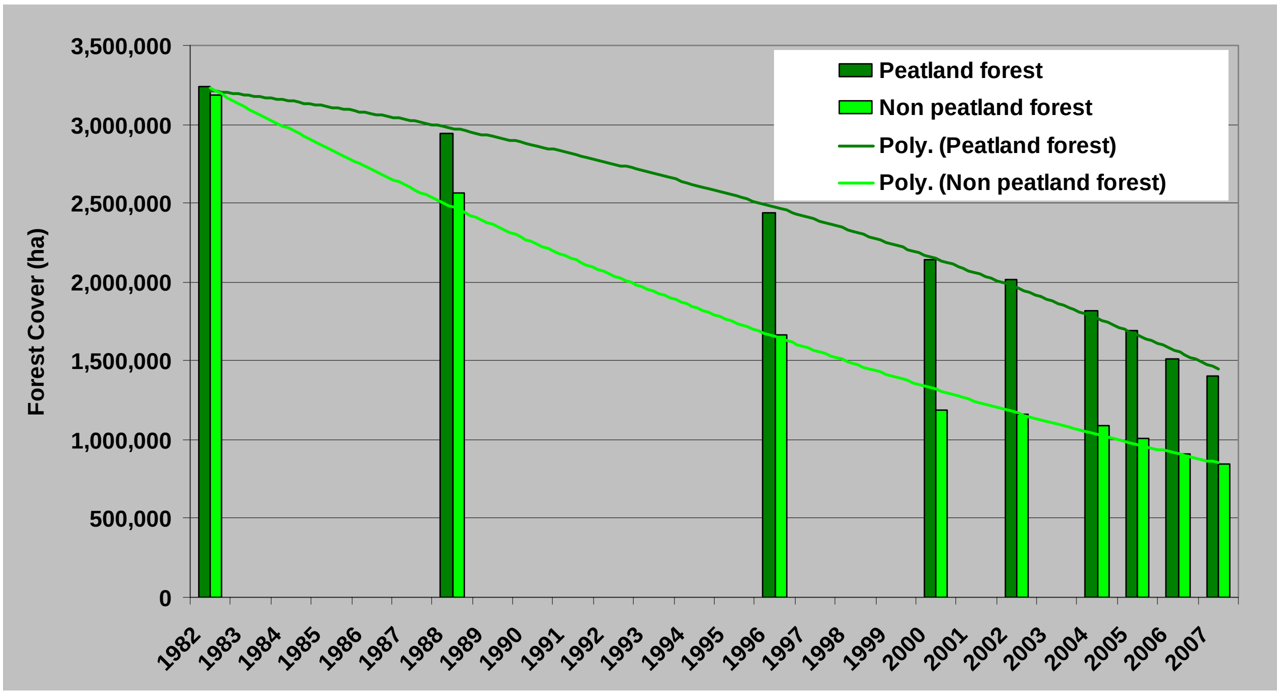
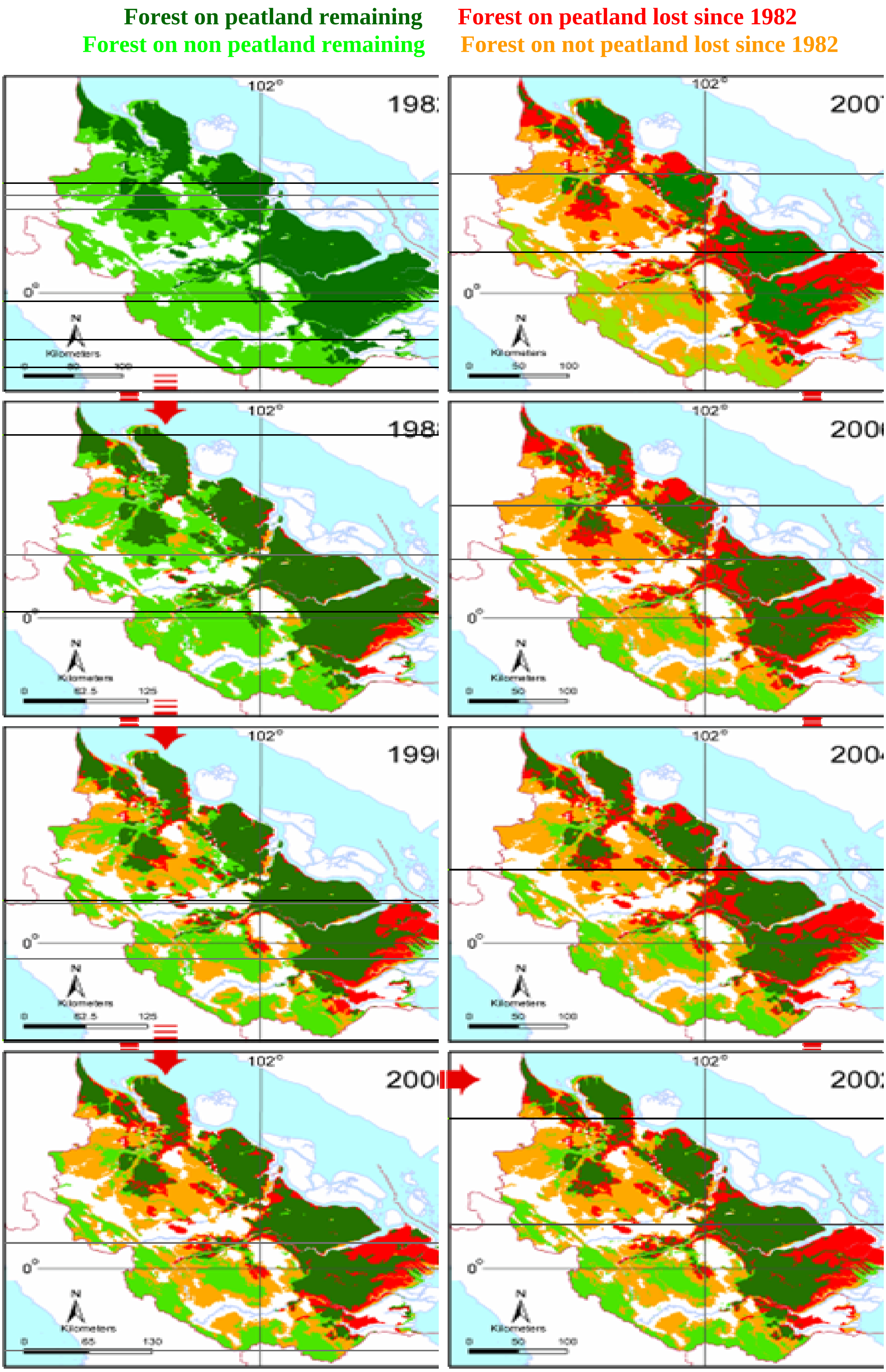


Figure 2.—*Forest cover on peat and non peat soils in Riau's mainland 1982 to 2007. A polynomial regression function of second order was used to display the deforestation trends (R^2 for both is >0.99).*

[vi] World Conservation Monitoring Centre, UNEP
[vii] Indonesian Ministry of Forestry
[viii] Indonesian Ministry of Forestry
[ix] WWF analysis of Landsat images since 2000



Map 3 a to h.—*Deforestation on peat and non peat soils in Riau's mainland 1982-2007.*

Average annual deforestation on both peat and non peat soils increased steadily between 1982 and 2000 (Figure 3), but then dramatically dropped for the years 2000 to 2002. These were important years for Indonesia's pulp & paper industry as the country's biggest producers, Asia Pulp & Paper (APP) and Asia Pacific Resources International Holdings Limited (APRIL), both defaulted on their national and international debt payments and stopped all investments. The companies operate two of the world's largest pulp mills in Riau.

From 2002 to 2006, deforestation steadily increased until by 2004-05 average annual conversion rates had reached the 1996-2000 levels (Figure 3). Deforestation between 2005 and 2006 was 286,146 ha -- 11% forest cover loss in just one year. But from 2005-2006 to 2006-2007, overall deforestation dropped by 37%. 2007 was another important year for Riau's pulp industry. In February, a de-facto natural forest conversion moratorium had gone into effect in the province due to a major police investigation into illegal logging by the resident pulp & paper industry[31] (Figure 3).

Until 2000, deforestation rates had been higher on non peat than on peat soil, but then, as non peat forests became scarcer, deforestation on peat soil began to outpace that on non peat soils (Figure 3).

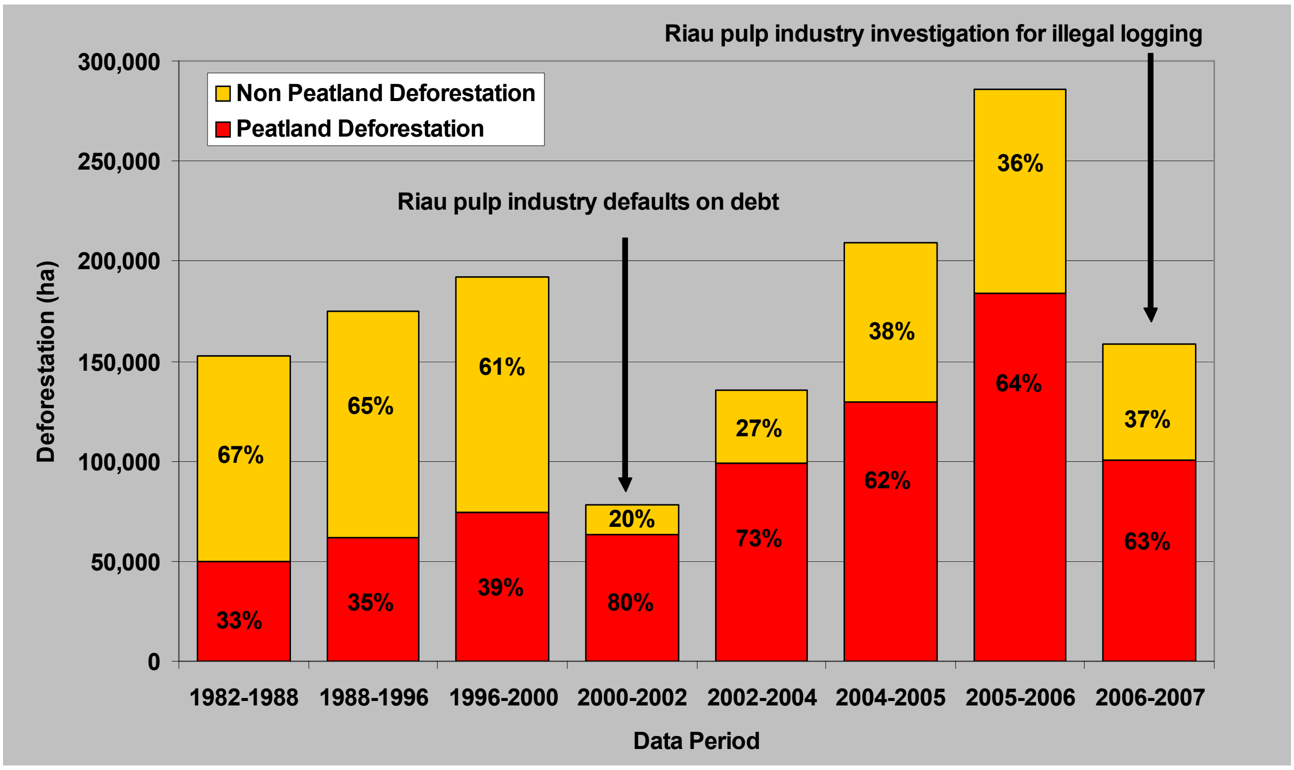
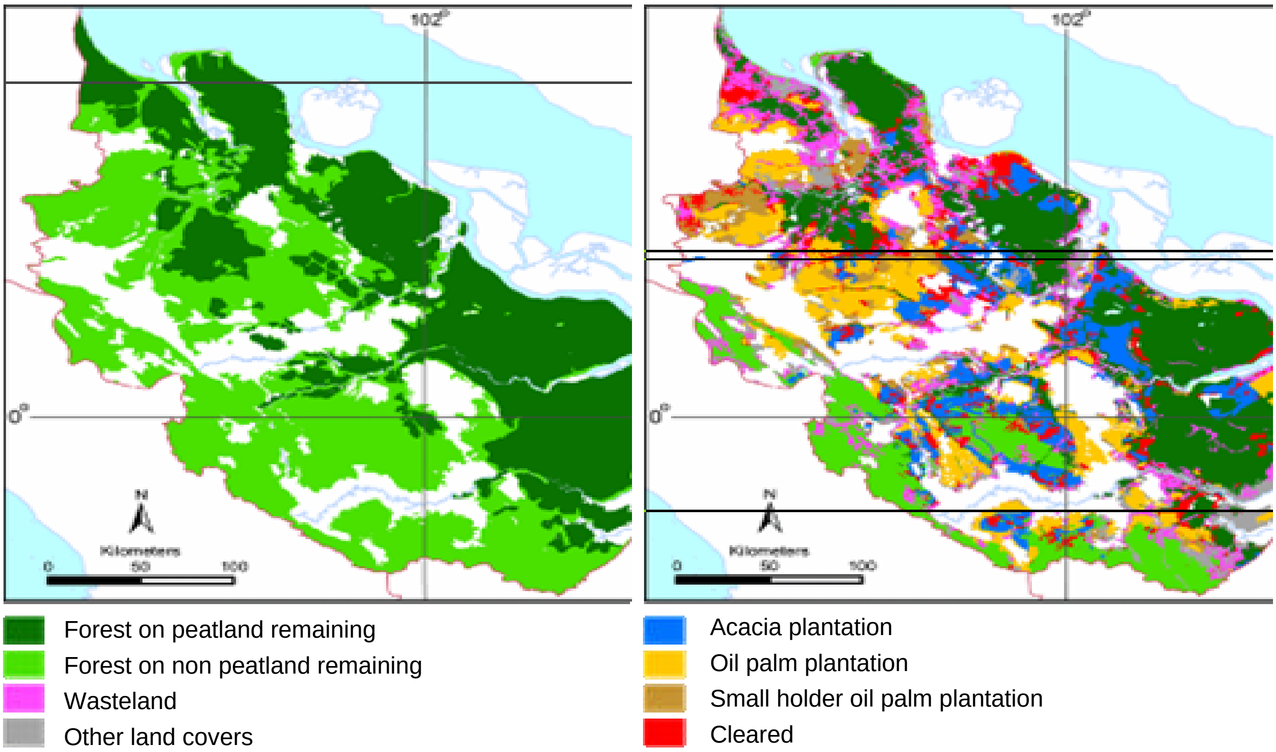


Figure 3.—*Average annual deforestation on peat and non peat soils in Riau's mainland 1982 to 2007.*

By 2007, Riau's land cover had dramatically changed. The once almost-contiguous forest in 1982, covering 78% of Riau mainland (Map 4 a), had been reduced to only 27%, fragmented into eight major forest blocks separated by mostly industrial plantations and wastelands (Map 4 b). The deforestation of Riau was driven by the palm oil and pulp & paper industries. Between 1982 and 2007, 28.7% (1,113,090 ha) of the cleared forests had been replaced by or cleared for industrial oil palm plantations, and 24.4% (948,588 ha) had been replaced by or cleared for acacia pulpwood plantations. So-called "waste" lands – lands that were deforested but not prepared for or covered with any identifiable crop cover – replaced 17.0% (659,200 ha). Many are concentrated north of Riau, close to the border with North Sumatra (Map 4 b). The remaining 29.9% of the cleared forests were replaced either by smallholder oil palm plantations (7.2%), appeared freshly cleared without an easily detectable future use in our analysis (4.6%), or were other land covers (18.1%), such as infrastructure, rubber, coconut and other plantations.



Map 4 a & b .— *(a) Peatland (dark green) and non peatland forest (light green) of the mainland of Riau in 1982. (b) Peatland and non peatland forest remaining in 2007 and various land covers that had replaced the 1982 forest by 2007.*

6.2 Deforestation of Riau's Protected Areas

Six percent of Riau's mainland is inside protected areas controlled by the national government (Appendix 2 PA) and 22% is province- and district-level protected areas (Kawasan Lindung), according to the currently active Riau Land Use Plan (RTRWP 1994). The national protected areas had on average 90.3% forest cover at the time of their declaration. The locally protected areas zoned in 1994 had 81.1% forest cover in 1996.

Locally and nationally controlled protected areas had lost much less natural forest by 2007 than unprotected forests had (Figure 4):

- Deforestation since declaration was less pronounced in nationally controlled protected areas (36,588 ha, 7.3% loss) than in provincial protected areas (269,188 ha, 18.7% loss).
- Wastelands on which forest had been cleared but not replaced by any crop were the largest non-forest land cover in both types of protected areas (together 214,237 ha).
- Acacia plantations for pulpwood had replaced more forest inside the protected areas than any other crop: 7.7% in provincial protected areas (136,215 ha) and 3.1% in nationally controlled protected areas (17,236 ha).
- Oil palm (both industrial and smallholder) closely followed acacia with 5.7% replacement in provincial protected areas (101,596 ha) and 3.2% in nationally controlled protected areas (18,056 ha).
- Smallholder oil palm plantations had converted relatively more forest in nationally controlled protected areas than in provincial protected forests, as compared to commercial oil palm and acacia plantations.

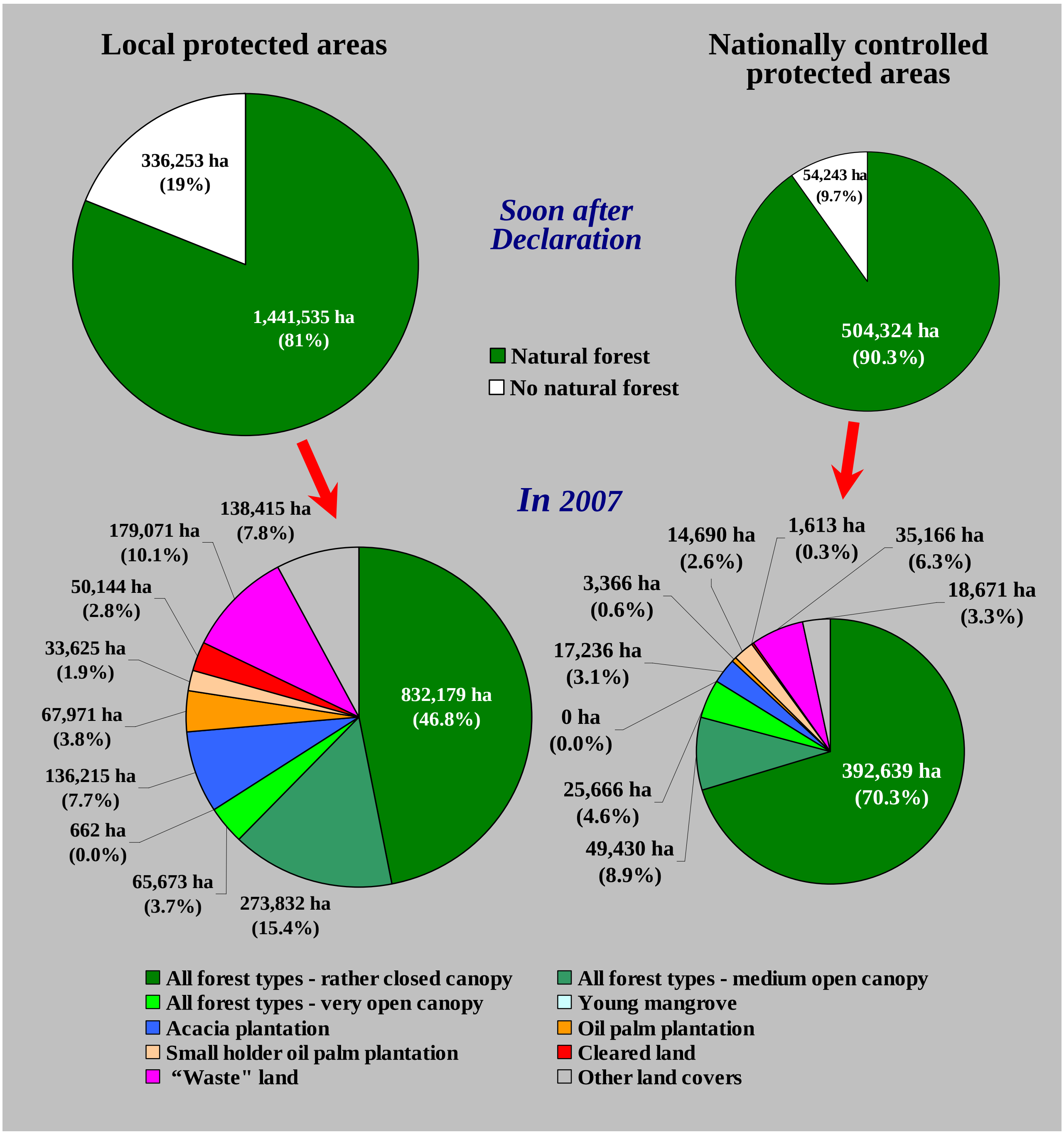


Figure 4.—*Original forest cover inside provincial-level protected areas (Kawasan Lindung, according to currently active 1994 Riau land use plan, RTRWP) and nationally controlled protected areas soon after declaration, and forest types and land covers inside the areas in 2007.*

6.3 Deforestation of Riau's TNBTK Landscape 1990 - 2007

For an in-depth analysis of deforestation, we focused on the Tesso Nilo–Bukit Tigapuluh–Kampar (TNBTK) Conservation Landscape comprising 55% (4,518,172 ha) of Riau's mainland. We created a detailed land cover GIS database for the TNBTK Landscape (Appendix 3 Map Support), distinguishing up to 50 land cover classes (Appendix 4 Land Cover) on dozens of Landsat TM/ETM images and one IRS image for four periods: 1990, 1995, 2000, and 2005 (Appendix 5 Satellite Images). For 2007, we did the same very detailed land cover analysis for the whole mainland of Riau. Images were analysed on screen with the minimum mapping unit fixed at ca. 50 ha. Land cover was digitized at a scale of 1:90,000. The accuracy of on-screen land cover interpretations was confirmed through frequent field verifications. A comprehensive database with GPS locations and photos of all field verification sites was compiled[32].

We distinguished natural forests as dry lowland, peat swamp, swamp and mangrove forest, and divided each forest type into four classes: rather closed canopy (crown cover (cc) > 70%), medium open canopy (70% > cc > 40), very open canopy (40% > cc > 10%), and cleared (cc < 10%). In the absence of a clear definition of what crown cover percentage constitutes forest under the yet-to-be-developed REDD mechanism for Indonesia, we defined "deforestation" as a change of natural forest with "rather dense," "medium open," and/or "very open canopy" to any other land cover class. Any forest area with a crown cover of <10% was considered deforested. Similarly, we defined "forest degradation" as any change in land cover from "rather closed" to "medium open" or "very open canopy," and from "medium open" to "very open canopy." Therefore, any change in crown cover between 100% and 10% was considered degraded.

For this analysis, we pooled the 37 land covers replacing natural forests into six major categories: 1. Acacia plantation, 2. Oil palm plantation, 3. Smallholder oil palm plantation, 4. Cleared land, 5. "Waste" land and 6. Other land covers. Peat swamp and swamp forests were pooled as "peatland forest."

6.3.1 Replacement of Dry Lowland versus Peatland Forest

By 2007, 42.1% (1,242,172 ha) of the TNBTK Landscape's 1990 forest cover had been lost. Pulpwood and oil palm plantations replaced 46.5% (577,911 ha) and 30.5% (378,478 ha), respectively, of all the lost forests. Smallholder oil palm plantations replaced 3.7%, wastelands replaced 7.5%.

Dry lowland and peatland forest were replaced at similar rates by the pulp & paper and palm oil industry, though more forests were replaced by acacia than by oil palm plantations (Figure 5).

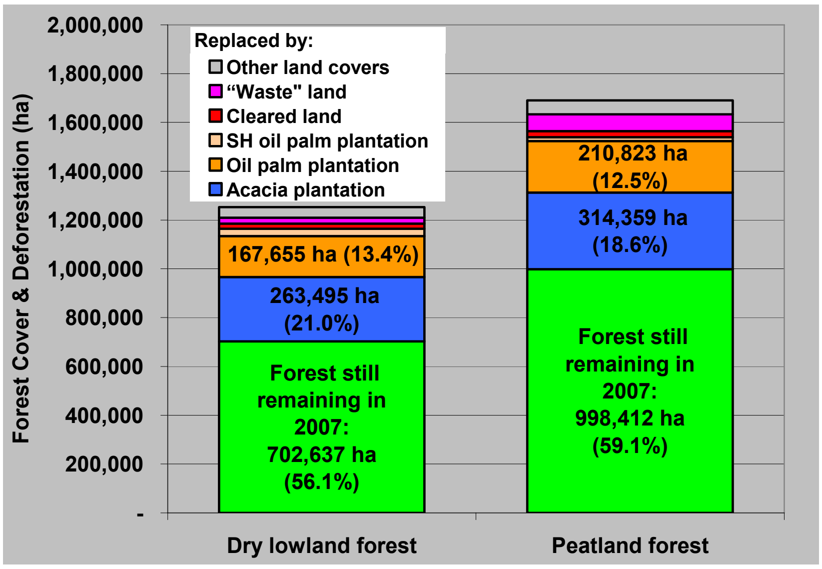


Figure 5.—*Replacement of 1990 dry and peatland forest by other land covers in the TNBTK Landscape by 2007. Green blocks show the natural forest remaining in 2007.*

6.3.2 Replacement of Closed Canopy Forests

Between 1990 and 2007, 90.3% of total deforestation was due to clearing of natural forest with a canopy cover of more than 40%: 601,856 ha of rather closed canopy with >70% closure and 519,760 ha of medium open canopy with > 40% closure. The pulp & paper industry replaced mostly closed and medium open canopy forest (Figure 6). The palm oil industry tended to replace forests with more open canopy covers (Figure 6).

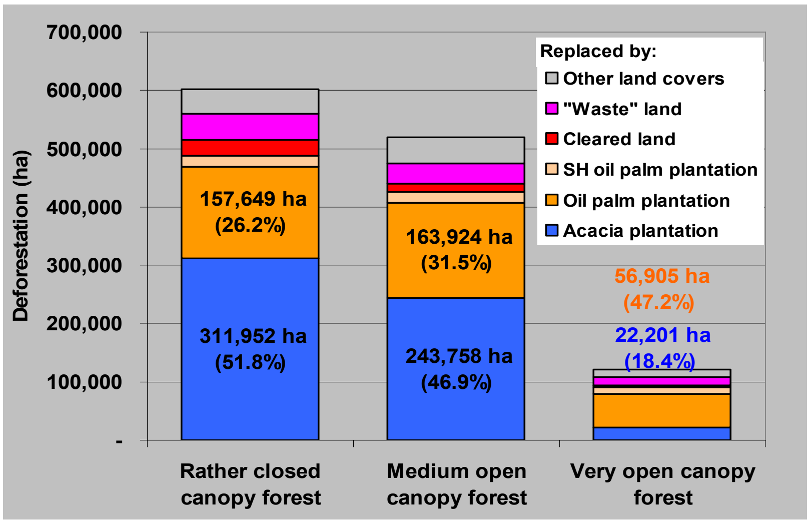


Figure 6.—*Replacement of forests with different canopy closures (>70%, 40-70%, and 10-40%) by other land covers in the TNBTK Landscape between 1990 and 2007.*

Between 1990 and 2007, 96.2% and 85.0% of the total deforestation caused by the pulp & paper and palm oil industries in the TNBTK Landscape, respectively, were of forests that had a canopy cover of more than 40% (rather closed canopy and medium open canopy forest) in 1990 (Figure 7).

The same trend was also seen in the other replacing land covers: smallholder oil palm plantations, "waste" lands, cleared lands and other land covers.

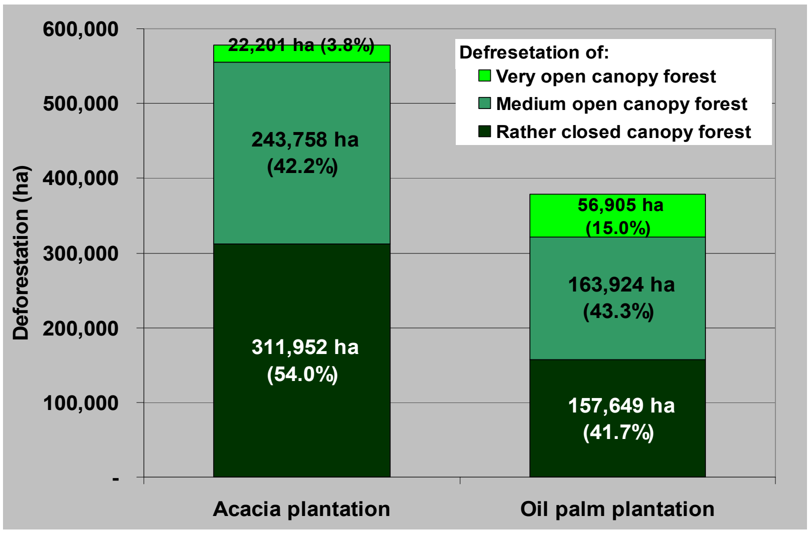


Figure 7.—*Replacement of forests with different canopy closures by acacia and oil palm plantations in the TNBTK Landscape between 1990 and 2007.*

From 1990 to 2007, dry lowland forest was increasingly cleared by the pulp & paper industry, mostly replacing forests with medium open and rather closed canopy (Figure 8 top). The palm oil industry replaced more dry lowland forests with medium open canopy and rather open canopy but slowed down after 2000. Compared to these two industries, no other single land cover group significantly contributed to forest replacement. The conversion trends were similar for peatland forest (Figure 8 bottom), except that both industries replaced more peatland forest with rather closed canopy than with more open canopies.

Map 5 shows the current land covers in Riau. In total, there are close to 900,000 ha of "waste" lands in the province outside national parks, where plantations could be developed without clearing natural forest. Around one-third of this is forest regrowth and the rest are shrublands and grasslands. Some of these areas could be developed into acacia plantations, instead of clearing natural forest.

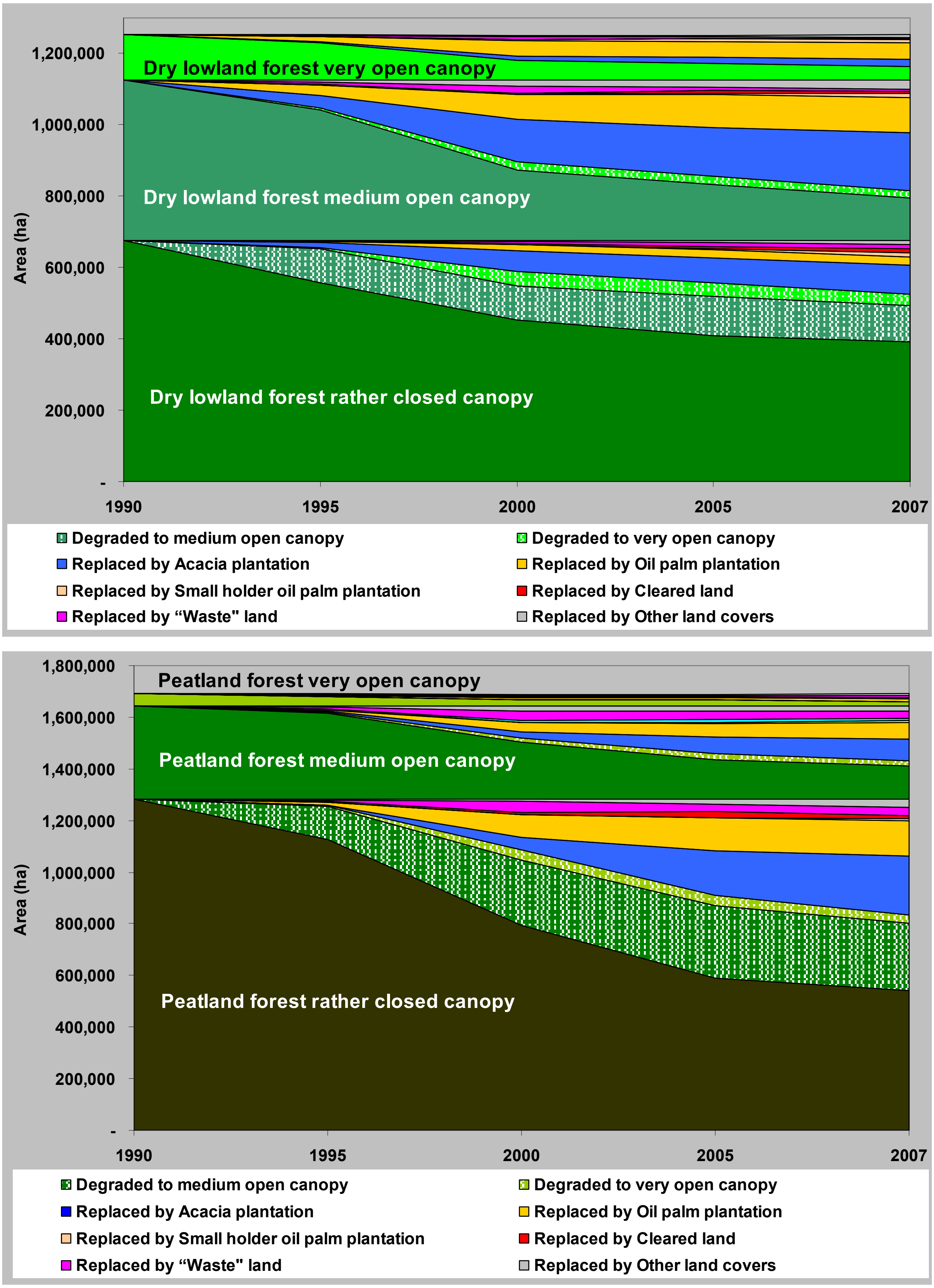
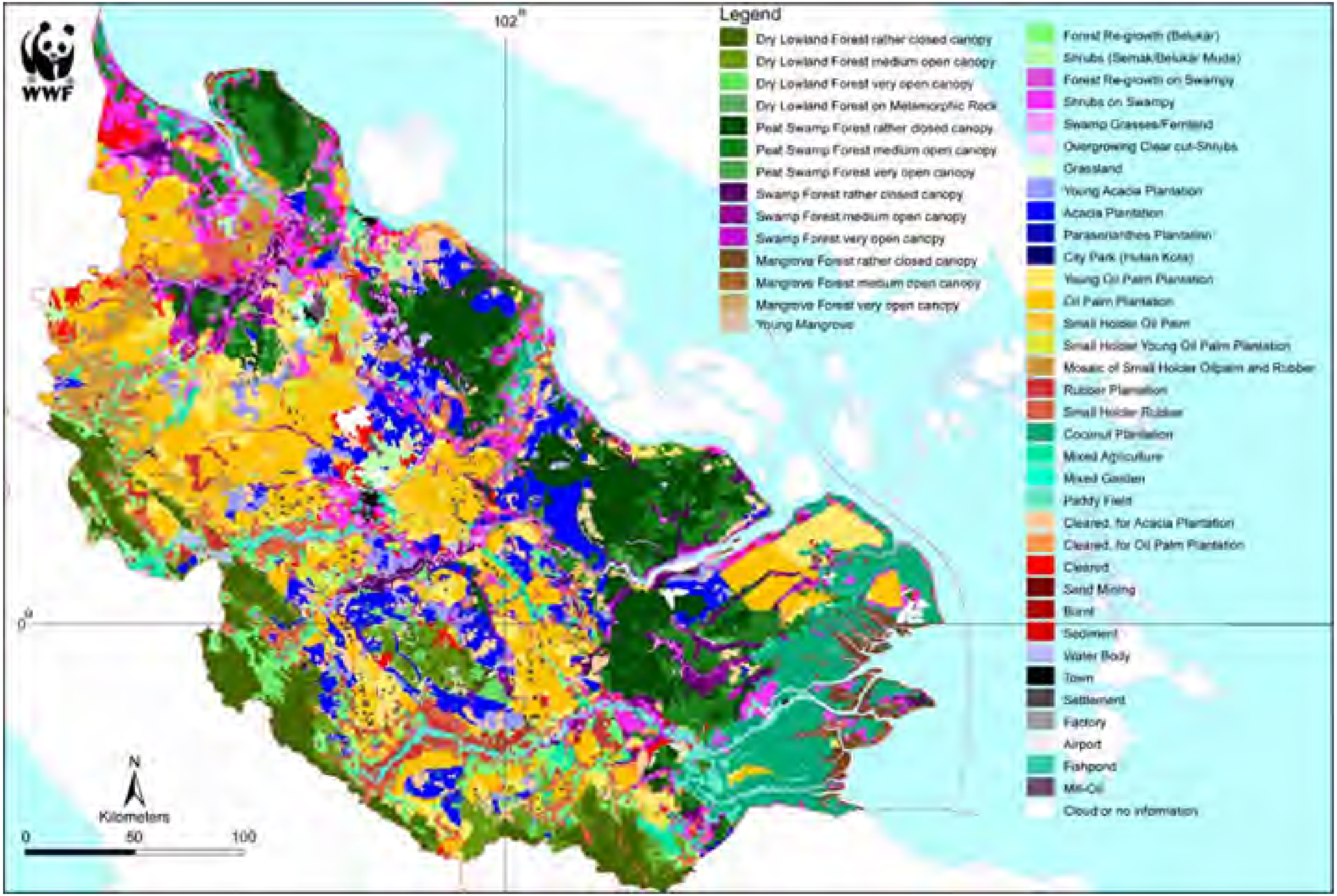


Figure 8 a & b.—*Replacement of dry lowland forest (a, top) and peatland forest (b, bottom) remaining in the TNBTK Landscape in 1990 by other land covers and forest degradation by 2007***.**



Map 5.—*Land covers in 2007 in Riau.*

6.4 Predicted Deforestation of Riau 2007-2015

We built two scenarios to predict deforestation between 2007 and 2015, the year until which Riau's new proposed land use plan is planned to be valid:

(1) "Business as usual"
We assumed:
- The current police investigation into illegal logging in the province is stopped and business as usual resumes.
- The annual deforestation speed stays the same as between 2005 and 2006 (183,859 ha/year for peatland forest and 102,287 ha/year for non peatland forest).
- All forests outside nationally controlled protected areas are cleared, but all forests inside protected areas remain as they were in 2007 (219,095 ha of peatland forest and 248,641 ha of non peatland forest). Pulpwood concessions are required by law to maintain some natural forest but compliance with that law has been checkered at best in the past. We assumed all natural forest would be converted.

(2) "Full implementation of draft Riau Land Use Plan 2015"
In May 2007, a new land use plan for Riau was submitted for stakeholder review. The proposed plan would replace the 1994 plan and suggests land use changes until the year 2015. The proposed plan contained 39 land zoning categories. To predict the effects the proposed land use plan might have on Riau's land cover by 2015, we pooled the 39 land zoning classes into 10 zoning classes all of which would have very similar effects on land cover (Appendix 6 Model).

We assumed:
- The pulp & paper industry succeeds in getting access to all forests that could legally be converted to pulpwood production and would prevail in all land-use zones where they are allowed, including three very minor zoning classes where other plantation types like rubber or oil palm would also be allowed. These minor zoning classes covered 4% of the natural forest predicted to be converted to acacia plantation by 2015.
- The May 2007 version of the draft land use plan, RTRWP 2015, is adopted as is.
- All suggested zoning changes are fully executed by 2015 and many natural forests are converted to plantations.
- Pulpwood concessions convert all natural forest in newly zoned areas.
- In a dramatic change from business as usual, law enforcement keeps all zones designated by the land use plan for protection of natural vegetation clear of encroachment and illegal logging.

We ran the two scenarios separately for peatland and non peatland forests, since deforestation on these two soil types has a different history and since it causes very different levels of CO_2 emissions. In Chapter 9, we will project CO_2 emissions based on these scenarios.

6.4.1 Predicted Forest Cover of Riau in 2015

Under the "Business as Usual" Scenario (1), peatland forest would continue to disappear until 2014, when all of the 1,188,355 ha of forest outside nationally controlled protected areas would have been cleared (Figure 9 a). This would result in an 84.4% loss of 2007 peatland forest and reduce mainland peatland forest cover to 3%. Under the "Land Use Plan" Scenario (2), peatland forest would disappear at a relatively slower pace. By 2015, the 791,829 ha forest zoned for conversion would have been cleared. This would result in a loss of 56.3% of 2007 peatland forest and reduce mainland peatland forest cover to 7%.

Under Scenario (1), non peatland forest would continue to disappear until 2013, when all of the 598,027 ha of forest remaining outside nationally controlled protected areas would have been cleared (Figure 9 b). This would be a 70.6% loss of 2007 non peatland forest; mainland non peatland forest cover would be reduced to

3%. Under Scenario (2), non peatland forest would disappear at a relatively slower pace. By 2015, the 209,921 ha of forest zoned for conversion would have been cleared. This would be a 24.8% loss of 2007 non peatland forest; mainland non peatland forest cover would be 8%.

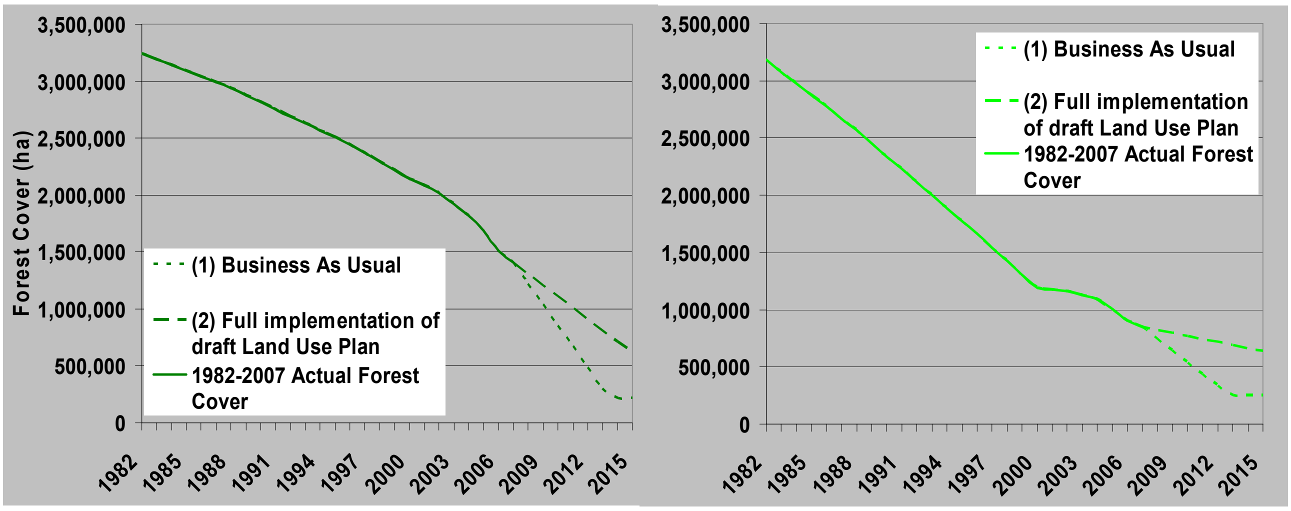
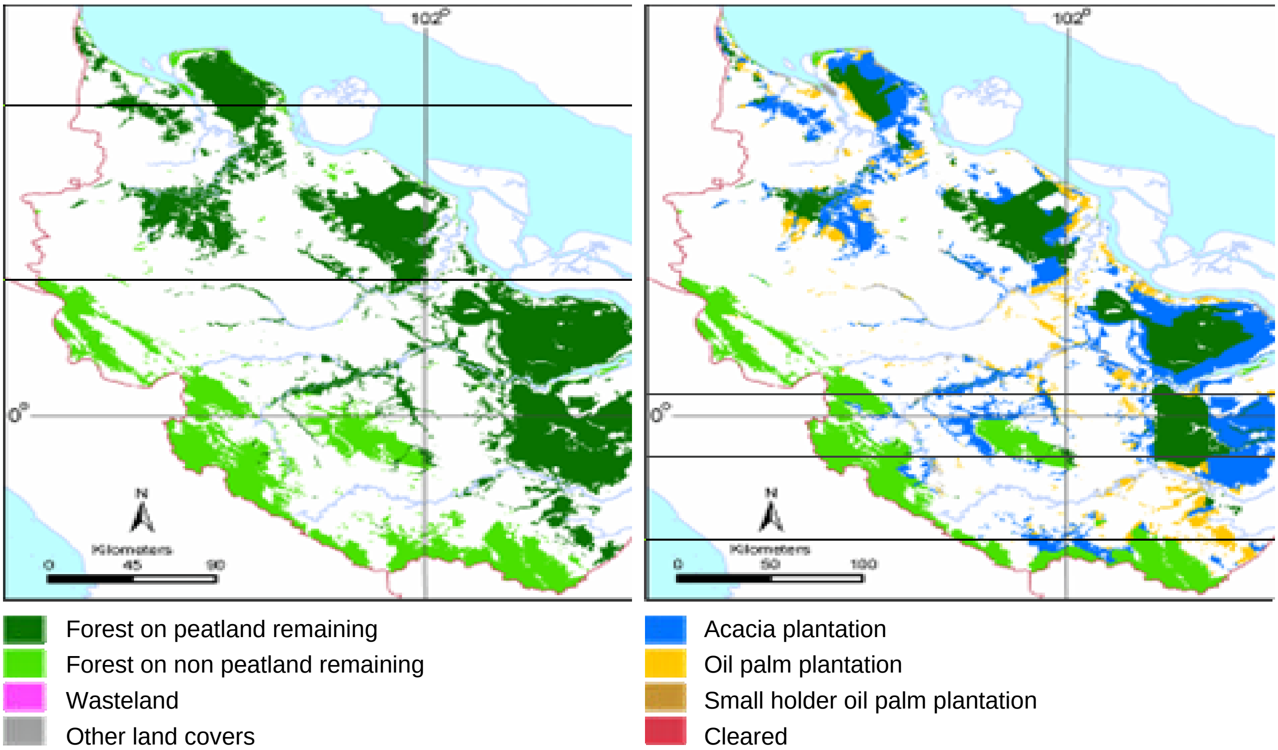


Figure 9 a & b.—*Peatland (a on the left) and non peatland (b on the right) deforestation 1982 to 2007 and two scenarios predicting deforestation from 2007 to 2015.*

6.4.2 Predicted Replacement of Forest in Riau by 2015[x]

Under Scenario (2) we predicted how the 2007 forest (Map 6 a) would be replaced by 2015; 47.4% of Riau's 2007 forest cover would be lost. The pulp & paper industry would by far be the most powerful driver of deforestation, expected to cause 73.6% of all new deforestation (Map 6 b). The palm oil industry would be the second most important driver, causing 22.5% of all predicted deforestation (Map 6 b).

[x] Forest and land cover data used for Scenario (2) calculations were from province-wide 2007 WWF Land Cover Data Base.



Map 6 a & b.—*(a) Peatland and non peatland forest with different canopy covers in 2007. (b) Peatland and non peatland forest with predicted canopy covers in 2015 and land covers predicted to replace the 2007 forest based on Scenario (2) "Land Use Plan 2015."*

6.4.3 Predicted Replacement of Dry Lowland versus Peatland Forest

Both dry lowland and peatland forests would be replaced mostly by pulpwood plantations (Figure 10). The draft land use plan even zones some mangrove forest for conversion.

84.3% of total deforestation between 2007 and 2015 would happen on peat soil.

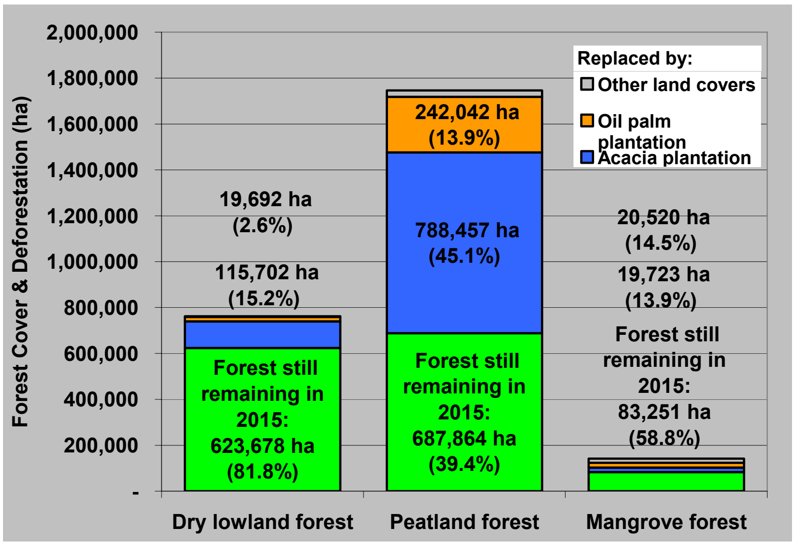


Figure 10.—*Replacement of natural forest remaining in 2007 by acacia, oil palm plantations and other land covers by forest type based on Scenario (2) "Full implementation of draft Riau Land Use Plan 2015." The green areas indicate the forest that would remain in 2015.*

6.4.4 Predicted Replacement of Closed Canopy Forests by 2015

85.6% of total deforestation between 2007 and 2015 would clear natural forest with a canopy cover of more than 40%, 434,763 ha of rather closed canopy with >70% closure and 640,730 ha of medium open canopy with >40% closure. The pulp & paper industry would clear most of that (Figure 11). Unlike during the 1982-2007 period, the pulp & paper industry would also be responsible for most of the clearing of forest with more open canopy with 40-10% closure (Figure 11).

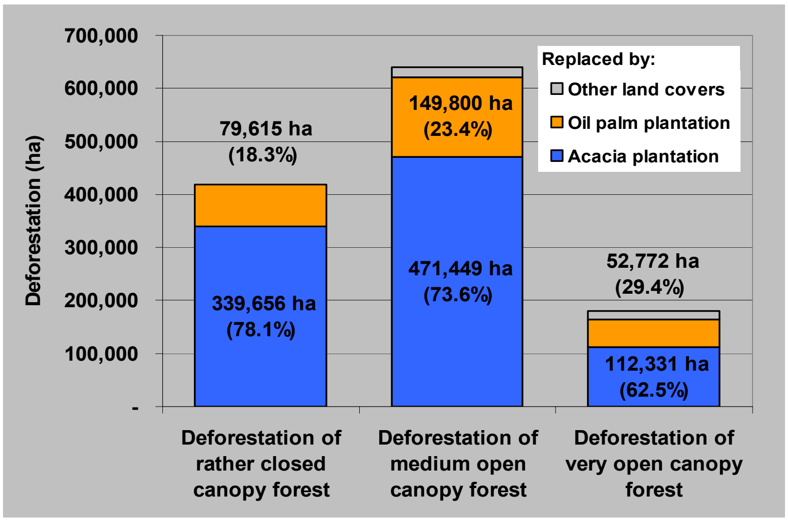


Figure 11.—*Predicted loss of forests with different canopy closures (>70%, 40-70%, and 10-40%) caused by acacia and oil palm plantations between 2007 and 2015 based on the Scenario (2) "Full Riau Land Use Plan Implementation."*

By 2015, 87.8% and 81.3% of the total deforestation caused by the pulp & paper and palm oil industry would be of forests with canopy closure of more than 40%, respectively (Figure 12).

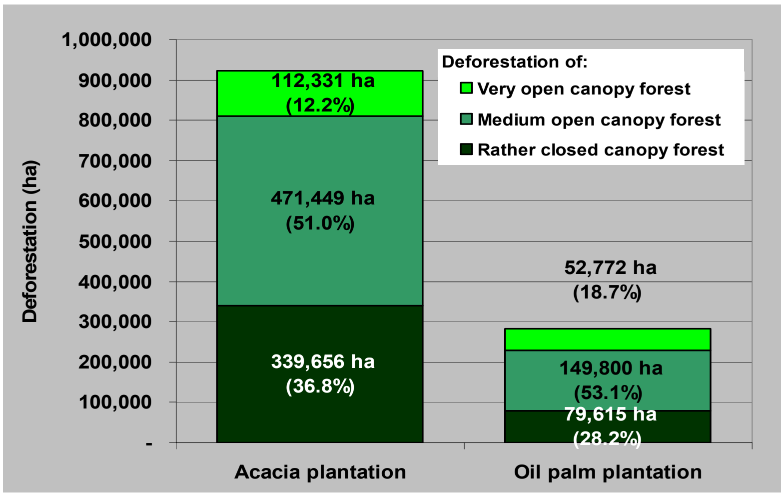
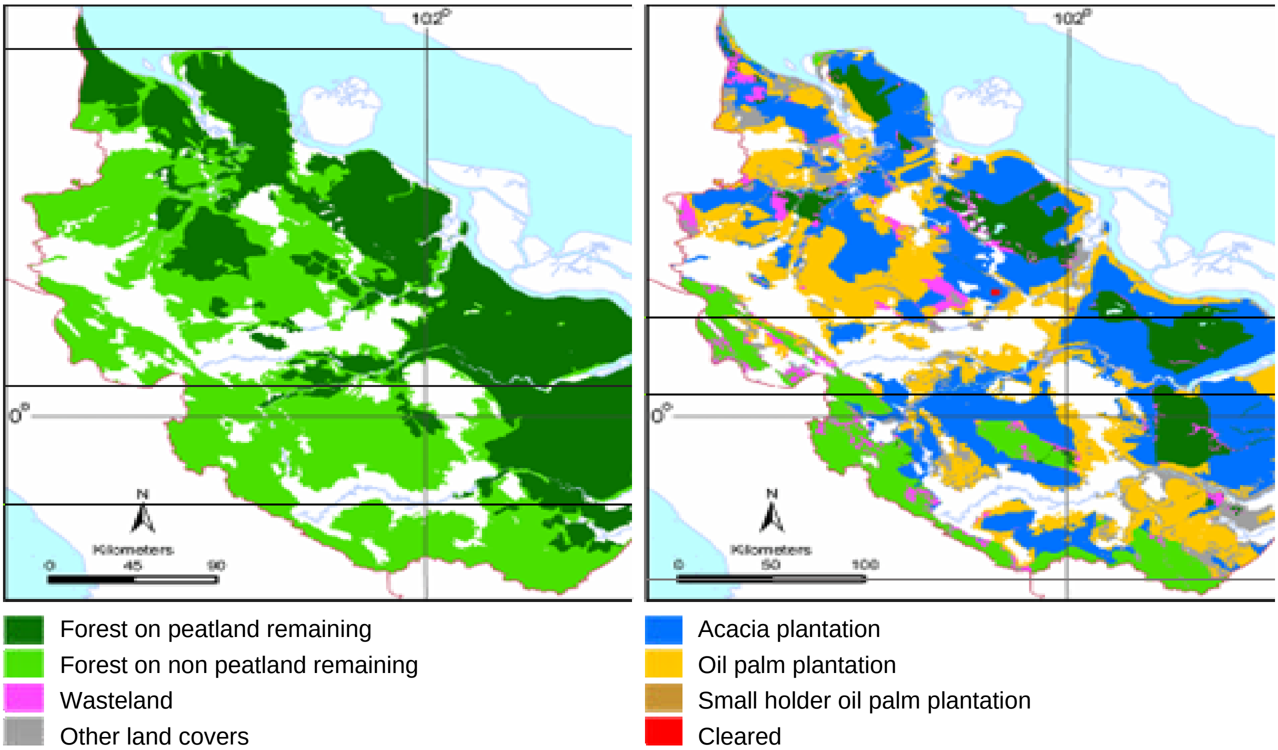


Figure 12.—*Projected replacement of forests with three classes of canopy cover by acacia and oil palm plantations in Riau between 2007 and 2015 based on the Scenario (2) "Full Riau Land Use Plan Implementation."*

Full implementation of the proposed land use plan by 2015 would completely isolate a few forest blocks in Riau's mainland in a sea of acacia and oil palm plantations (Map 7 a & b). Over the 33 years since 1982, acacia plantations and oil palm plantations would have replaced 36.4% (1,872,470 ha) and 27.2% (1,395,344 ha), respectively of all the forest lost.



Map 7 a & b.—*Natural forest with different canopy covers, acacia and oil palm in 1982 and predicted for 2015 based on Scenario (2) "Full implementation of draft Riau Land Use Plan 2015."*

7. REDD – Degradation

We analyzed canopy closure as one indicator of forest degradation for the TNBTK Landscape between 1990 and 2007 (Appendix 4). We defined "forest degradation" as any change in land cover from "rather closed" to "medium open" or "very open canopy," and from "medium open" to "very open canopy." Therefore, any negative change in crown cover between 100% and 10% was considered degraded.

In Chapter 10, we relate forest degradation in the Landscape to carbon loss, estimating past CO_2 emissions.

7.1 Forest Degradation in Riau's TNBTK Landscape 1990– 2007

Dry lowland and peatland forest showed the same basic trends of degradation (Figure 8 and Table 1):

- From 1990 to 1995, 10-14% of both forest types degraded from rather closed to medium open canopy, but there was only limited deforestation.
- After 1995, deforestation accelerated and continuously increased, especially in peatland forests.
- After 1995, the degraded portion of the original dry lowland forest remaining in each time period stayed more or less the same (14.6 – 19.8% with medium canopy), while degradation of peatland forest strongly increased until 2005 (10.2 – 30.9% with medium canopy).
- By 2000, the speed of peatland forest deforestation had overtaken that of dry lowland forest.
- By 2007, 15.1% (102,493 ha) of 1990's dry lowland and 20.0% (256,976 ha) of 1990's peatland forest with rather closed canopy had been degraded to medium open canopy forest – in addition to the 22.2% and 35.2%, respectively that had been deforested.
- Throughout the period, the percentage of rather closed forest degraded to rather open canopy stayed quite small in both forest types.
- Both forest types with medium open canopy hardly ever degraded to very open canopy; instead, most medium open canopy forest was immediately deforested.

Table 1.—*Percentage by which 1990 forests with closed canopy had been deforested and degraded in subsequent time periods.*

	1990	*1995*		*2000*		*2005*		*2007*	
	ha	*% of 1990*	*% of 1995*	*% of 1990*	*% of 2000*	*% of 1990*	*% of 2005*	*% of 1990*	*% of 2007*
Dry Lowland Forest in									
still rather closed canopy	*677,070*	*82.4*	*85.1*	*67.0*	*76.9*	*60.3*	*73.3*	*57.9*	*74.5*
degraded to medium open canopy	*0*	*14.1*	*14.6*	*14.0*	*16.1*	*16.3*	*19.8*	*15.1*	*19.5*
degraded to very open canopy	*0*	*0.3*	*0.3*	*6.1*	*6.9*	*5.6*	*6.8*	*4.7*	*6.0*
Loss of 1990 closed canopy forest	0	3.2	NA	12.9	NA	17.7	NA	22.2	NA
Peatland Forest in									
still rather closed canopy	*1,283,273*	*87.9*	*89.6*	*61.9*	*73.1*	*45.9*	*64.8*	*42.3*	*65.2*
degraded to medium open canopy	*0*	*10.0*	*10.2*	*19.7*	*23.3*	*21.8*	*30.8*	*20.0*	*30.9*
degraded to very open canopy	*0*	*0.2*	*0.2*	*3.0*	*3.5*	*3.1*	*4.4*	*2.5*	*3.9*
Loss of 1990 closed canopy forest	0	2.0	NA	15.4	NA	29.2	NA	35.2	NA

7.2 Forest Degradation in Riau's Protected Areas

In 2007, nationally controlled protected areas (Appendix 2 PA) had more forests with rather closed canopy (70.3%, 392,639 ha) than provincial protected areas (46.8%, 832,179 ha).

8. Fires (1997 – 2007)

The use of fire for land clearing has a long tradition in Indonesia. It is manifested in traditional agricultural slash-and-burn practices. Most of the fires can be ascribed to human activities, independent of whether they occur in natural forest, shifting cultivation or plantation areas[33]. Often it is just negligence in the sparsely inhabited and vast peatlands that causes a fire to run out of control into adjacent forest areas[34,35,36].

Fire occurrence was analysed using two different low-resolution satellite sensors: 1.) the National Oceanic and Atmospheric Administration Advanced Very High Resolution Radiometer (NOAA AVHRR) and 2.) the Moderate Resolution Imaging Spectroradiometer (MODIS)[37]. Both systems are well-established to detect active burning fires, so-called "hotspots," at a spatial resolution of 1 km. in tropical regions[38]. To estimate the fire-affected area each recorded hotspot coordinate was converted to an area of 1 km² equivalent to the approximate spatial resolution of the sensor[39]. This does not mean that the resulting burnt area is necessarily the same size; fires may cover the whole square km or only a small fraction. However, it has been shown that there is a good correlation between burnt areas determined from hotspots and burnt areas derived from high resolution Landsat imagery[40,41]. The area estimate is conservative, because the burnt area is often underestimated by the hotspot approach: 1.) fires are detected only once or twice a day and rapidly spreading fires escape recording, 2.) smoke from the fire often impedes the detection of hotspots and 3.) ground fires in forests are not hot enough to be detected from space. Areas of overlapping hotspots were considered to be burnt only once.

Between 1997 and 2007, 72,435 fire events (hotspots) were recorded in Riau. Most fires occur during the main dry season. In Riau, it usually lasts for about 3 months from June to August. During El Nino episodes the dry season can extend to 4 months or more. Figure 13 shows fire hotspots and frequency over 11 years in Riau. The years 1998, 2005, and 2006 had more than 8,000 hotspots. These exceptionally high numbers of fires were related to the extended drought conditions of El Niño episodes, in 1997-1998 and 2005-2006.

In 2005, the MODIS sensor detected 19,396 hotspots in Riau. 79% of all hotspots occurred on peat. Fires on peat are responsible for transboundary haze and release huge amounts of carbon dioxide into the atmosphere[42]. Over the past 11 years, 31% of the land surface of Riau was burnt at least once, 12% was burnt more than once. Such recurrent fires are a serious threat to rainforest ecosystems: the more often an area is affected by fire, the lower its chance for successful forest regeneration and the higher the degradation of the original forest ecosystem[43,44].

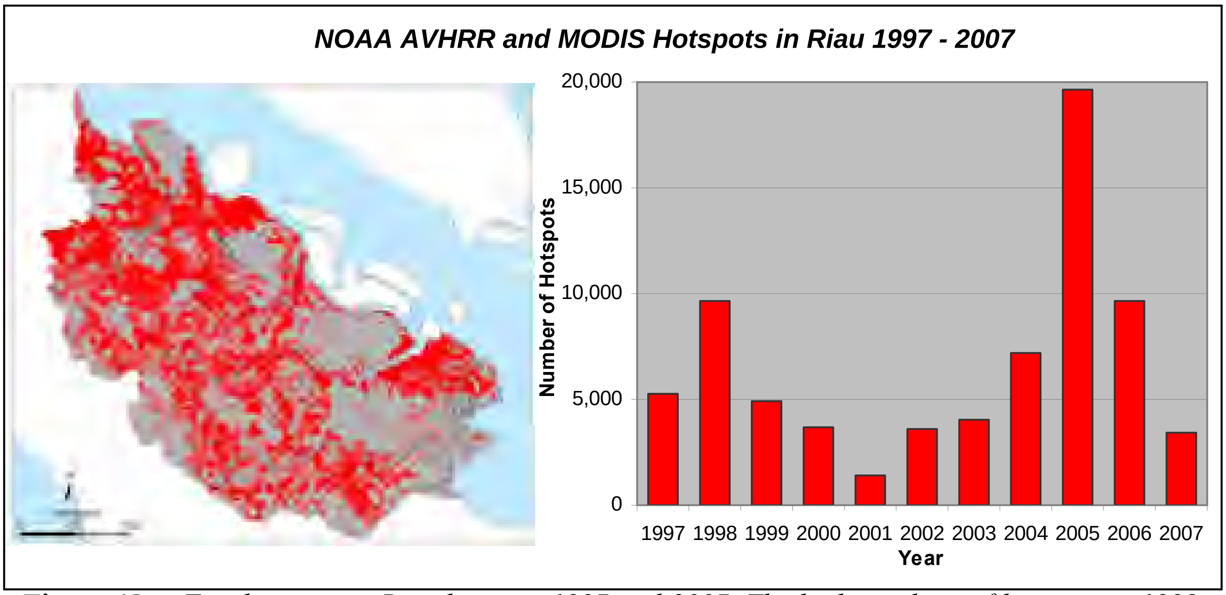


Figure 13.—*Fire hotspots in Riau between 1997 and 2007. The high numbers of hotspots in 1998, 2005 and 2006 are linked to extended drought conditions during El Niño episodes.*

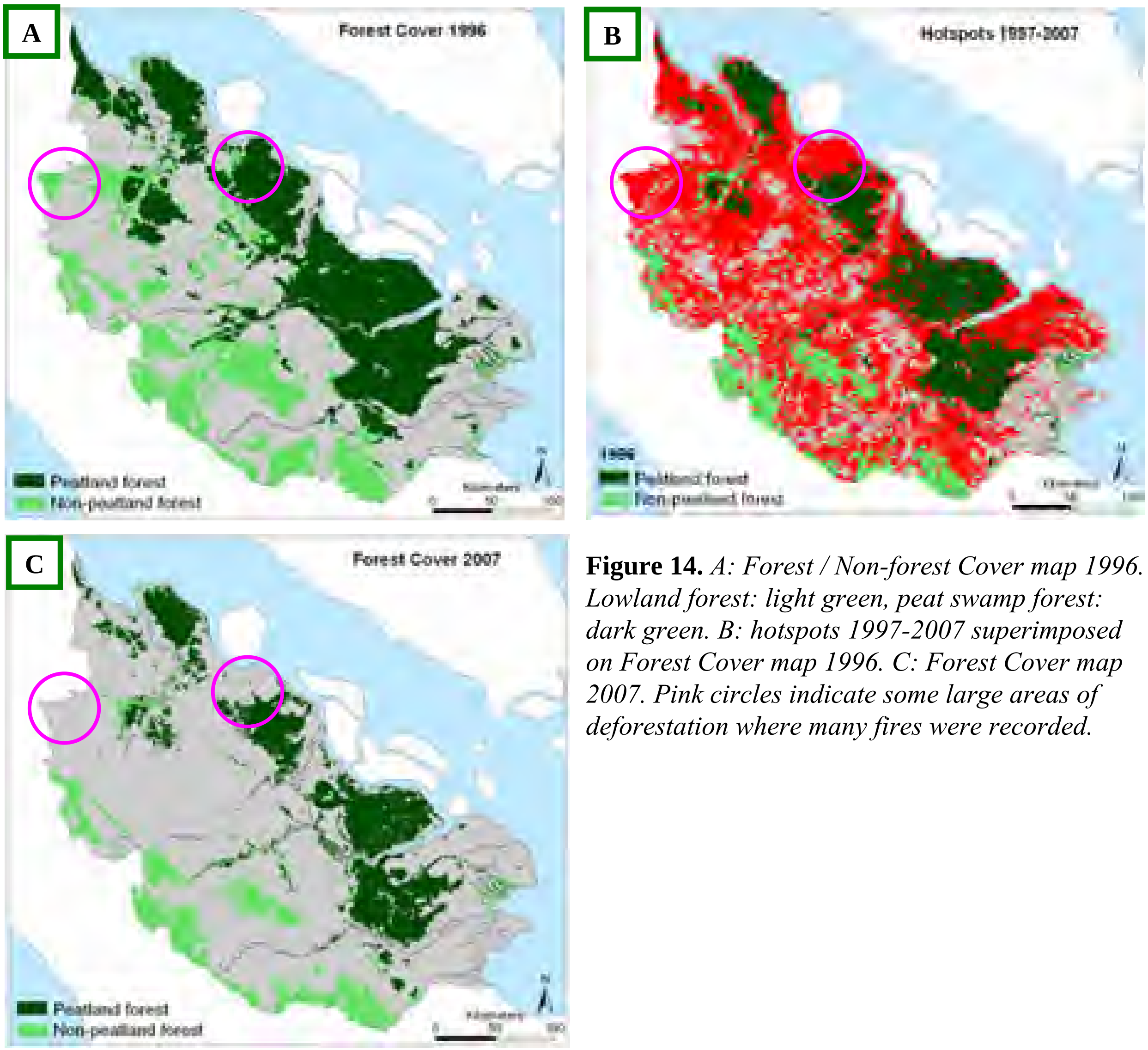


Figure 14. *A: Forest / Non-forest Cover map 1996. Lowland forest: light green, peat swamp forest: dark green. B: hotspots 1997-2007 superimposed on Forest Cover map 1996. C: Forest Cover map 2007. Pink circles indicate some large areas of deforestation where many fires were recorded.*

Figure 14 shows 1996 and 2007 forest covers and all hotspots recorded from 1997 to 2007. 34% of all hotspots occurred in forests, while 66% were recorded on non-forest land covers. Of all hotspots in forests, 67% were recorded on peat swamp forests.

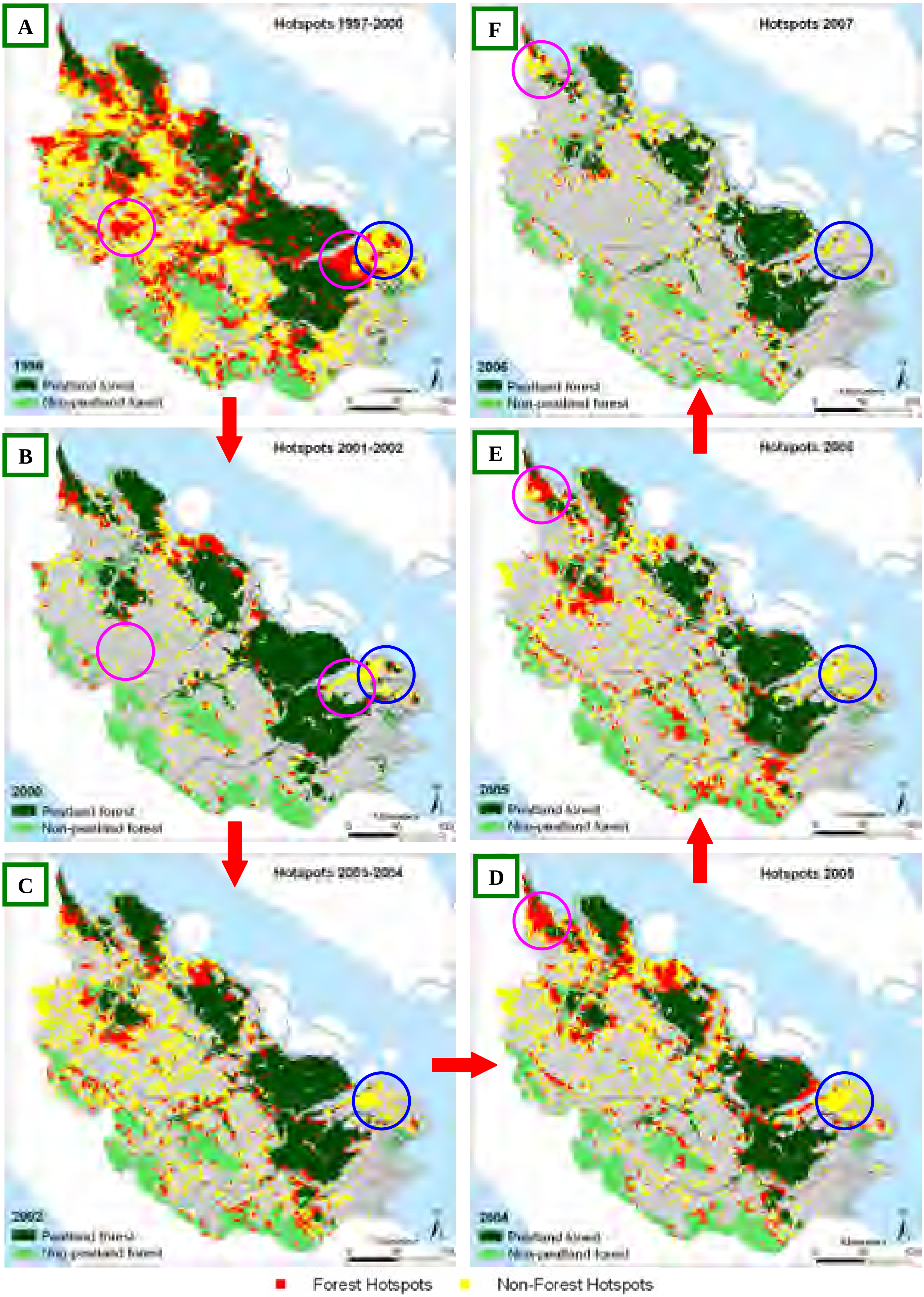


Figure 15.—*Fire occurrence over 11 years. Hotspots on forest are shown in red, hotspots non-forest land covers are shown in yellow. Large deforestation events coinciding with fire occurrences are marked by pink circles. Blue circles indicate recurrent fires on coastal peat soils.*

We compared successive years of land cover change and fire occurrence. In Figure 15, all hotspots of a specific period are superimposed on the respective forest cover map. Hotspots in forests are displayed in red, hotspots in non-forest land covers are shown in yellow. In Figure 15A, all hotspots recorded between 1997 and 2000 were superimposed on the land cover map of 1996. Many fires occurred in areas that were forested in 1996 (red colored dots). Most fires in forests (either dry or peat swamp forests) occurred at the boundary of forest blocks while very few fires were recorded inside. This was observed also in other similar ecosystems in Indonesia[45,46,47]. In Figure 15B, all hotspots recorded between 2001 and 2002 were superimposed on the 2000 land cover map. Some large areas of peat swamp forest burnt. In Figure 15C-F, hotspots were always superimposed on the forest cover map of the previous year. Many sites with forest fires were no longer forested in subsequent years. There clearly is a link between fires and deforestation, although it cannot be determined whether fires caused the initial deforestation or were used to clear the land for planting after it had been logged. Significantly fewer fires were observed in 2007 (Figure 15F, Figure 16). This may be attributed to two factors: 1.) 2007 was a wet year due to persistent La Niña conditions in the region (almost no fires were recorded inside closed forests) and/or 2.) a province-wide police investigation stopped all clear-cutting of forests by the plantation industries, thus preventing a need to clear land for planting. Figure 16 shows the relationship of forest/non-forest hotspot recordings

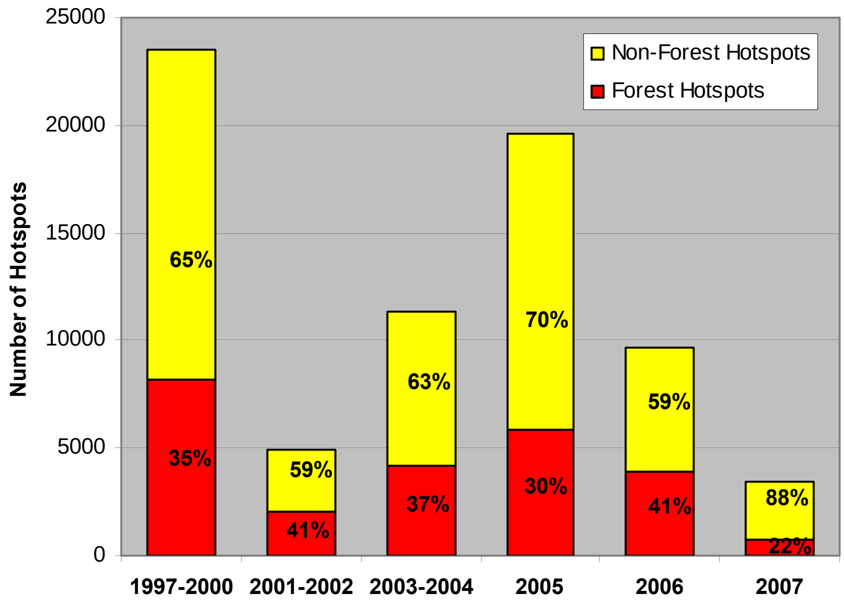
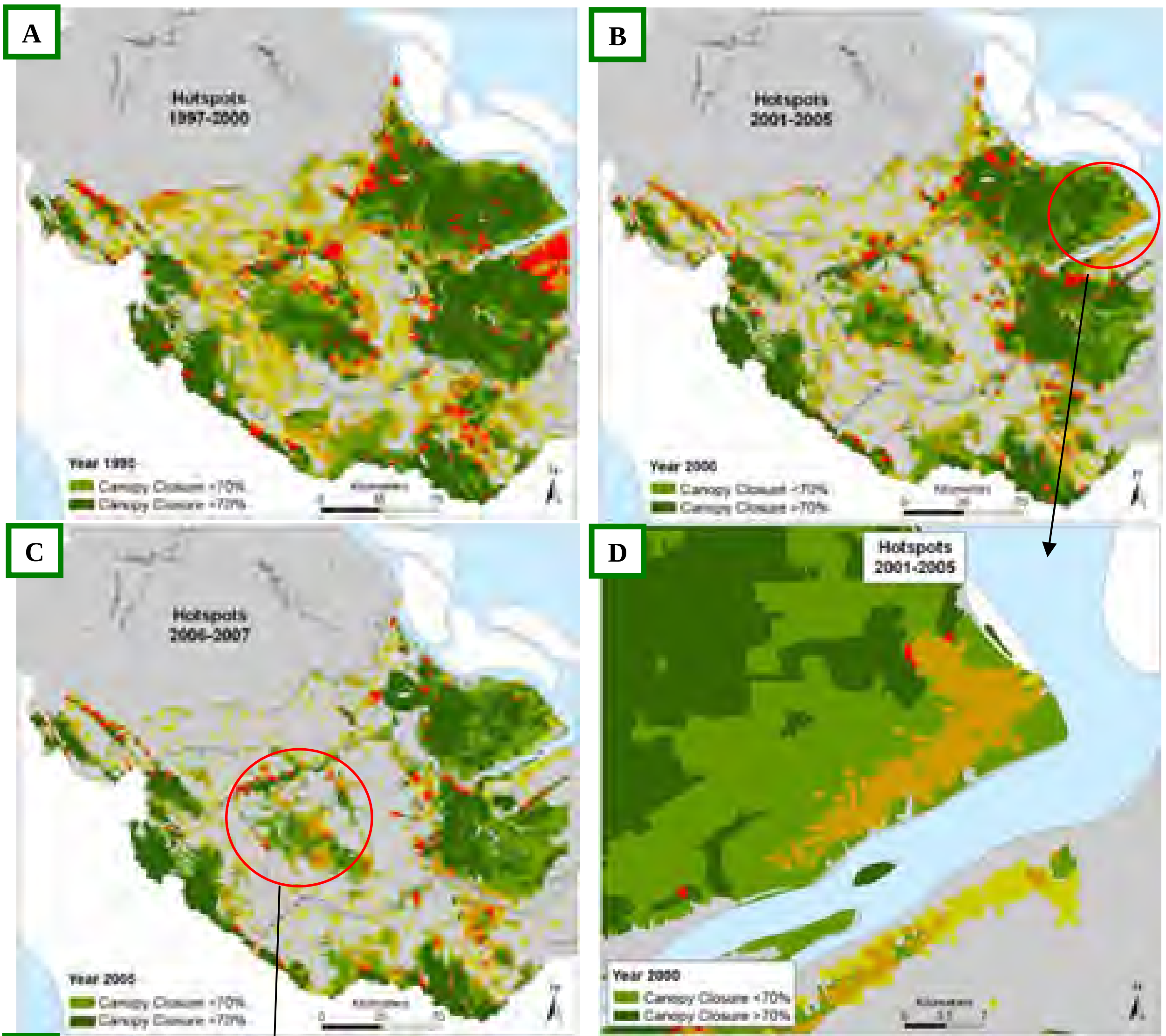


Figure 16.—*Relationship of forest/non-forest hotspots for successive periods.*

In Borneo and the Amazon, disturbance of the forest canopy by logging and other processes significantly increased the probability of fire[48,49]. This started vicious cycles leading to more forest degradation, recurrent fires and finally, strongly degraded, fire-prone bush and savanna ecosystems. We studied successive years of forest degradation and fire occurrence in the TNBTK landscape comparing how many fires occurred in closed canopy forests versus relatively open canopy forests.

Most fires occurred in areas with forests with canopy closure of less than 70% (Figure7); few forests with canopy closure of more than 70% were affected (Figure 8). This confirms results obtained in Borneo[50].



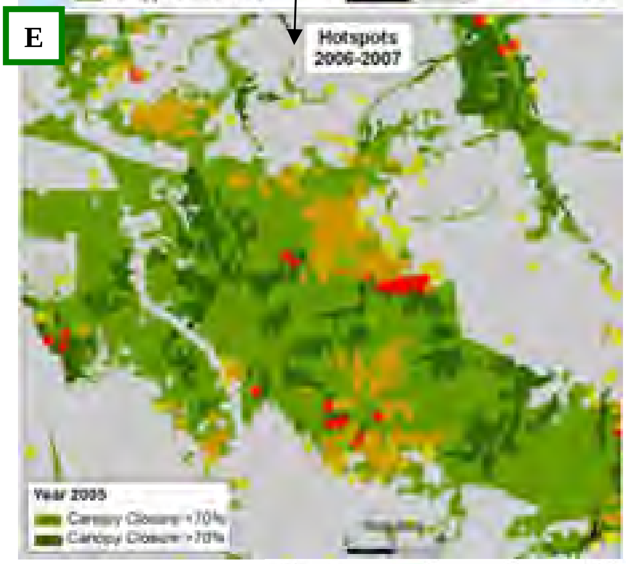


Figure 17.—*Fires in the TNBTK landscape from (A) 1997–2000 on 1995 forest cover, (B) 2001–2005 on 2000 forest cover, and (C) 2006–2007 on 2005 forest cover. Fires on forest with "Canopy Closure >70%" are shown in red, on forest with "Canopy Closure <70%" are shown in orange, and on non-forest are shown in yellow.*

In the enlarged areas, the Tesso Nilo forest (D) and Kampar Peninsula (E), almost all fires were recorded in forests with "Canopy Closure <70%".

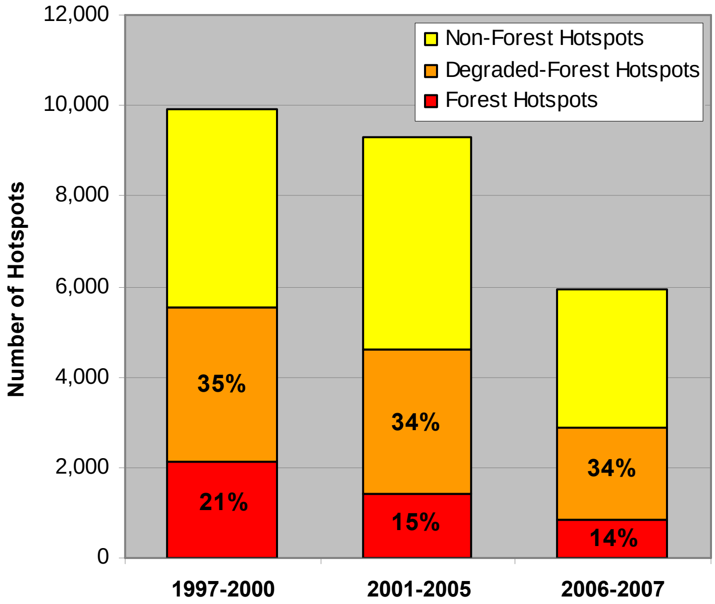


Figure 18.—*Hotspots on non-forested, open canopy, and closed canopy areas in successive periods.*

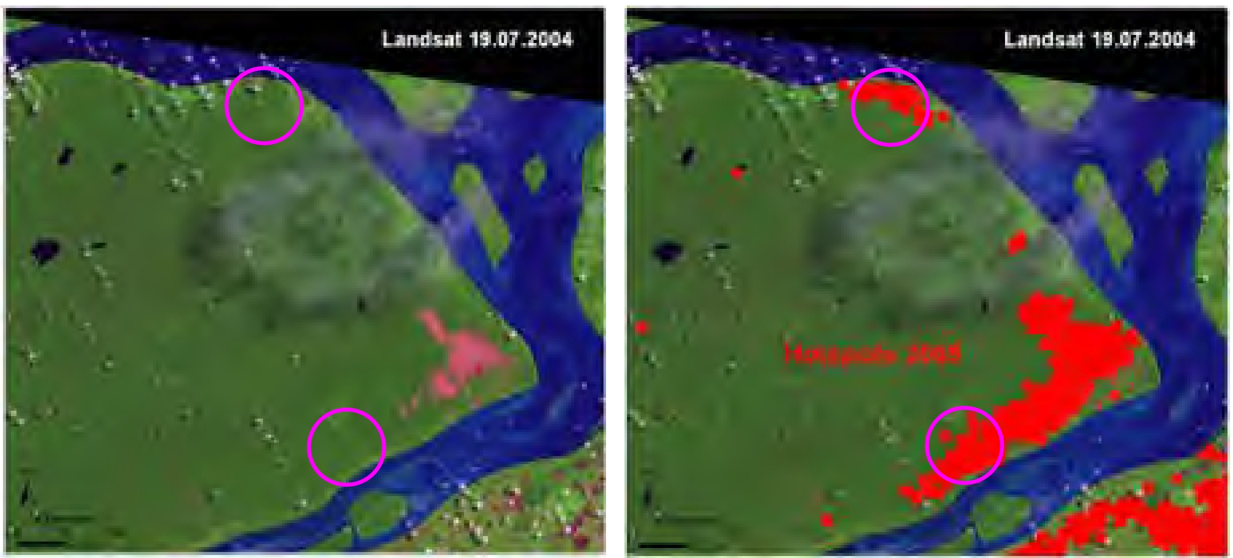
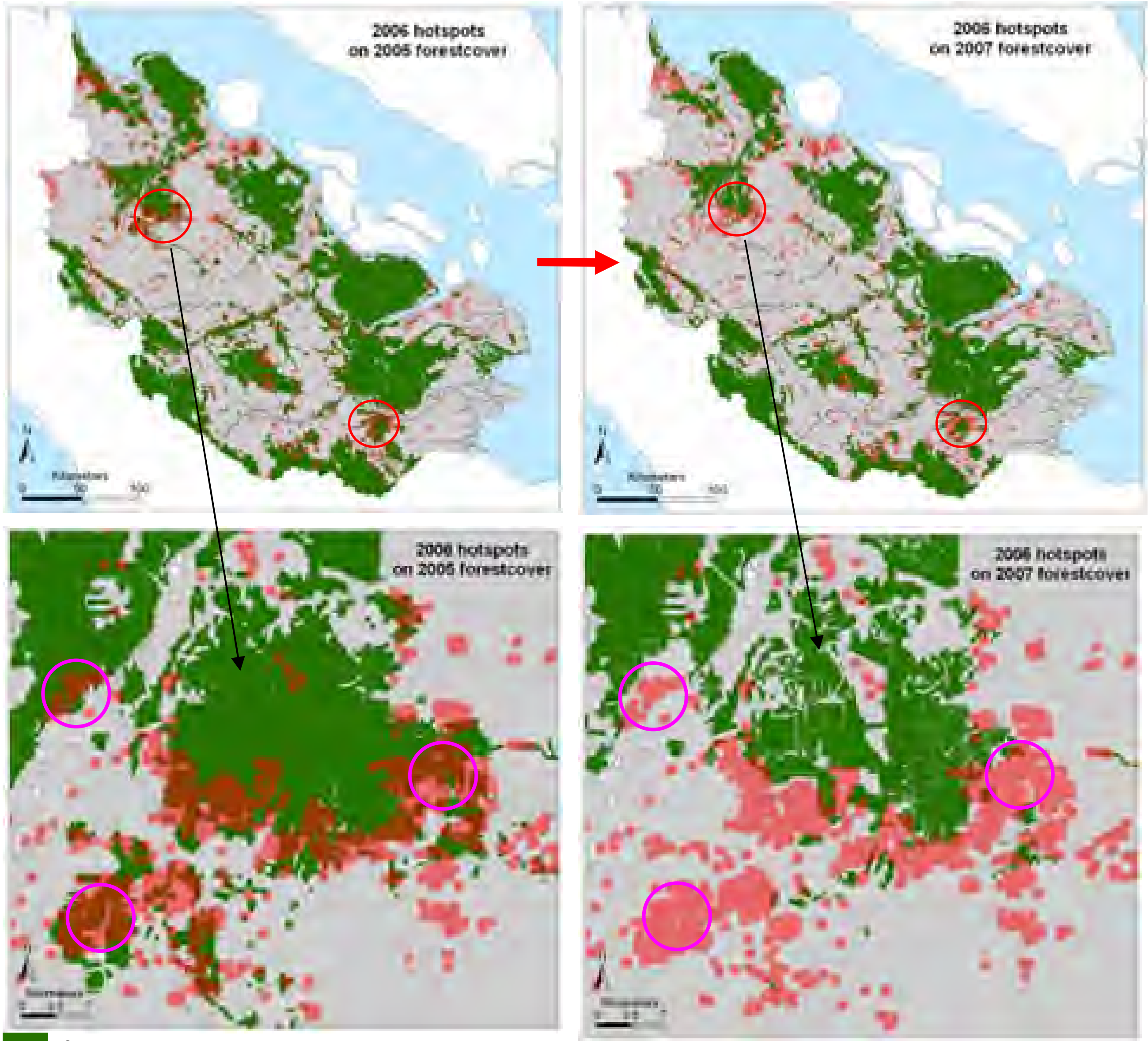


Figure 19.—*Landsat ETM images acquired in the years 2004 and 2005. Hotspots are shown in red and are superimposed in the right panel. Deforested and burnt areas are indicated by pink circles.*
The lower circles show how fire may have been used to clear land for an Acacia pulp wood plantation associated with Asia Pulp & Paper (APP) in 2004.

Satellite images of the eastern tip of Kampar peninsula at very high resolution show areas that have hotspots as being deforested in the next year (Figure 19).

We analyzed how many hotspots recorded in 2005 were located inside the forested areas of 2004 and 2006. 5,830 of the 2005 hotspots were located on areas forested in 2004. Of these, 4,832 hotspots were located on areas not forested in 2006. About 83% of the 2005 fires were associated with deforestation.

In Figure 20, we show forest cover changes between 2005 to 2007 and associated hotspots in Riau's Libo forest block where Riau's pulp and paper industry conducted vast forest clearings during these years.



forest
hotspots on forest
hotspots on non-forest

Figure 20.—*2006 fires superimposed on forest covers of 2005 and 2007. The enlarged areas show Riau's Libo forest block where large forest conversions by Riau's pulp and paper industry occurred. Dark red: hotspots on forest, light red: hotspots on non-forest. Pink circles show areas where deforestation was associated with fire.*

5,830 of the 2005 hotspots were located on areas forested in 2004. Of these, 4,832 hotspots were located on areas not forested in 2006. About 83% of the 2005 fires were associated with deforestation.

3,931 of the 2006 hotspots were located on areas forested in 2005. Of these, 3,312 hotspots were located on areas not forested in 2007. About 84% of the 2006 fires were associated with deforestation. Of that 20% today are oil palm plantations, 37% acacia plantations and 4% other plantation crops. Over 60% of the land in which deforestation was associated with fire in 2006 had become plantations by 2007.

About one-quarter of deforestation in Riau was associated with fire in the last few years. Between 2004 and 2006, 525,576 ha of forest disappeared. 28% of this area (144,845 ha) was affected by fire in 2005. Between 2005 and 2007, 477,349 ha of forest disappeared. 27% of this area (126,428 ha) was affected by fire. 44% of the deforested area was converted to plantations. On 29% of these newly established plantations, fire was recorded.

Fires in Protected Areas

Only 8% of the nationally recognized protected areas of Riau have been affected by fire between 1997 and 2007 (Figure 21).

Some small protected areas such as Sungai Dumai, Balai Raja Duri, and Pusat Latihan Gaja as well as half of Sultan Syarif Kasyim Minas Protected Area – all located in the northern and middle part of Riau – have been seriously burnt. Three other nationally recognised protected areas (Giam Siak Kecil, Bukit Bungkuk, and Tesso Nilo) were affected by fire along their borders. Seven large protected areas were almost not affected by fire (Figure 21). Small protected forest patches appear to be at much higher risk to be burnt than large contiguous forests, probably because the latters' canopy closure is usually better as they are less accessible to illegal loggers and encroachers.

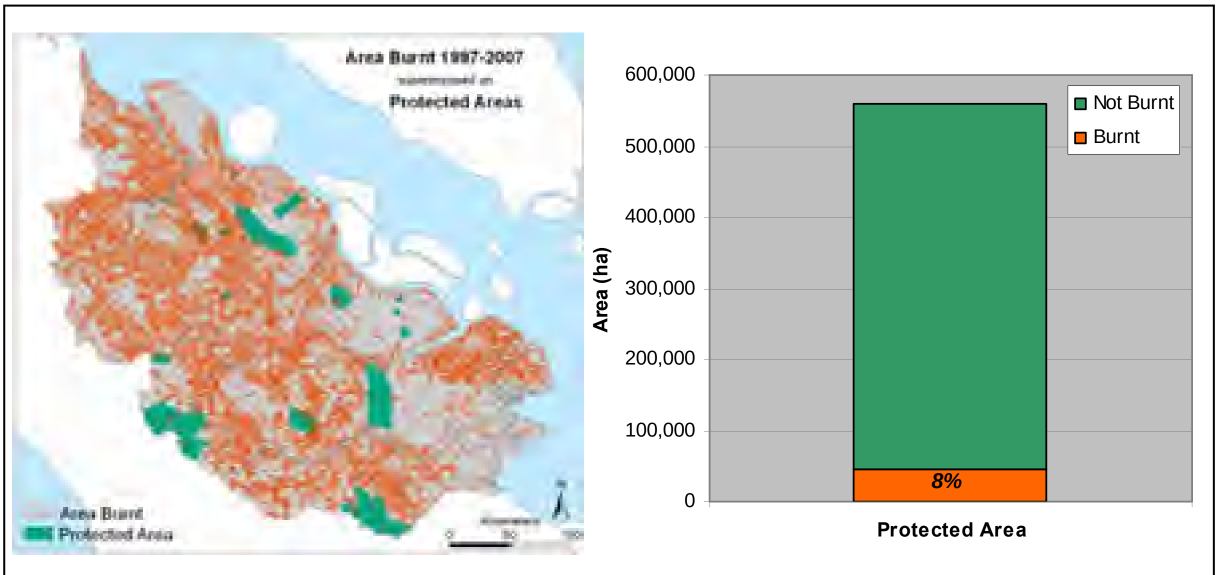
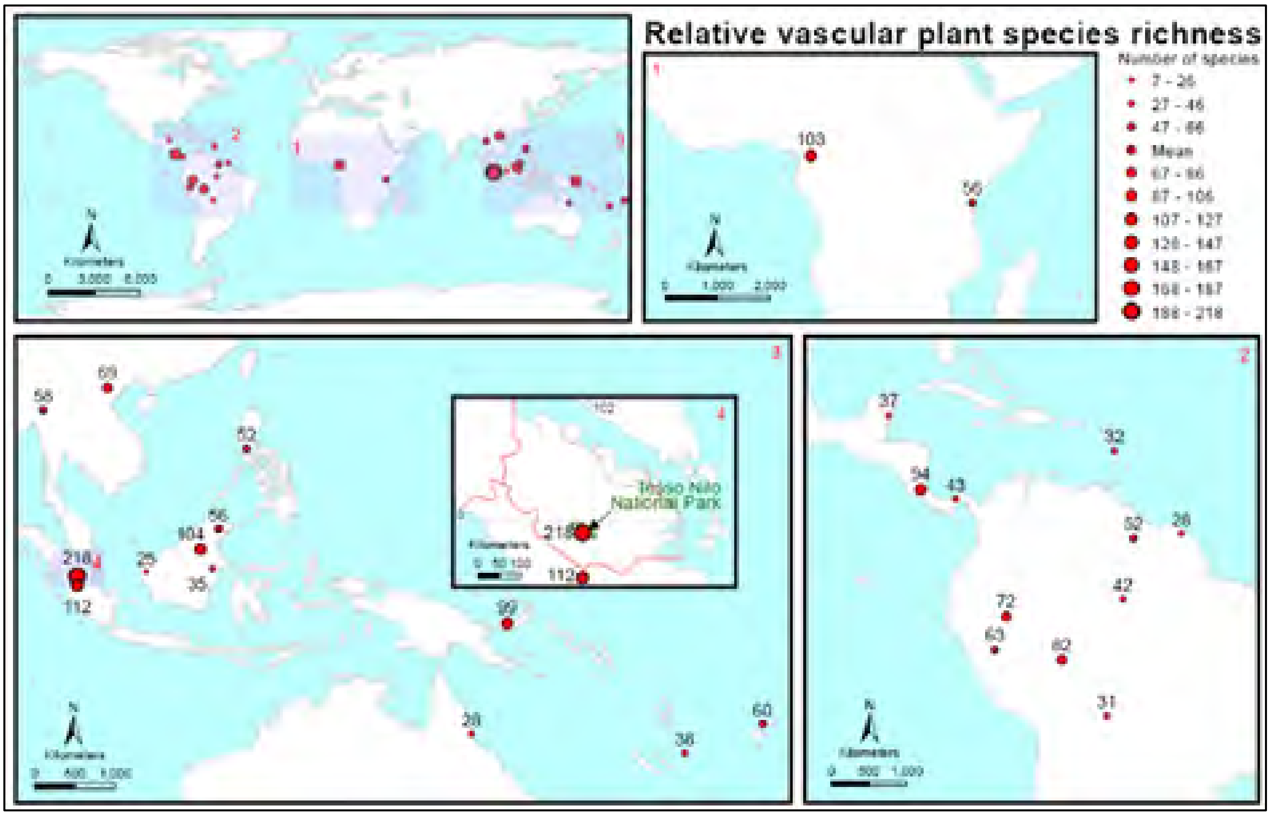


Figure 21.—*Fire occurrence (red dots) in nationally recognized protected areas (green polygons).*

9. Biodiversity

9.1 Forest Diversity in Riau

A global comparative study found central Riau's dry lowland Tesso Nilo forest to have a higher vascular plant species diversity than any other tropical forest around the world included in the study[51] (Map 8). Second in diversity were other forests in Sumatra, in the province of Jambi. The study found no published records available that indicate similar levels of plant species richness anywhere else in the world's lowland forests. Using the same recording method for plant-based biodiversity, Tesso Nilo's species richness was well above that of the richest sites recorded until then in more than 1,800 plots in tropical lowland forests between sea level and 550m elevation in 20 countries or island dependencies, including Australia, Bolivia, Brazil and Peru (East and West Amazon basin), Cameroon (Congo Basin), Costa Rica, Fiji, Guyana, France (French Guyana and Martinique), Kenya, Indonesia (Borneo and Java), Malaysia, Mexico, Papua New Guinea, Panama, Philippines, Thailand, Vanuatu and Vietnam.



Map 8.—*Relative vascular plant species richness of study sites in tropical forests around the world.*

A study by Indonesia's Academy of Science, LIPI, found Riau's Tesso Nilo forest to be more diverse than other forests on the island of Sumatra[52] (Table 2). Upon the discovery of the astounding diversity levels in the Tesso Nilo forest, LIPI recommended to the Indonesian Ministry of Forestry that the forest be protected. But by 2007, four years later, only one-fourth of the originally surveyed forest had been protected by the Government. Approval by the Ministry of Forestry to also zone the remaining area as a national park has been pending since 2001.

Table 2.—*Comparison of tree species richness in six forest study sites in Sumatra, Indonesia*[2].

Locations	Plot Size (ha)	Number of Tree Species	Tree Density (/ha)	Species Richness Index
Tesso Nilo Forest Complex	1	215	557	9.11
Alas River, Leuser National Park, Aceh	1	81	542	3.48
Ketambe Research Forest, Leuser National Park, North Sumatra	1.6	132	480	4.76
Bukit Tigapuluh National Park, Jambi	0.09	30	610	4.04
Rimbo Panti (800 m asl), North Sumatra	1	145	429	7
Rimbo Panti (200 m asl), North Sumatra	1	80	451	3.76

Tesso Nilo forest in Riau © WWF.

9.2 Status of Riau's Sumatran Elephant Population and Habitat

Sumatran elephants in Riau oil palm plantation. © WWF

Riau's elephant population was estimated four times between 1985 and 2007 (Figure 22, Table 3). All elephant population estimates were rough. Survey numbers were based on interviews with local communities, observations during human-elephant conflict situations, and evidence collected during dung pile and track surveys. Survey teams delineated the approximate ranges of apparently distinct elephant herds (so-called elephant pouches), and estimated how many elephants were likely associated with each pouch.

Elephant numbers dropped from an average 1,342 in 1984 to 210 in 2007 (Figure 22), a decline of 84% over 23 years, faster even than Riau's 65% forest loss over the same time period (Figure 22). The number of elephant pouches increased from 11 in 1984 to 16 in 1999 as forests became more fragmented and herds of elephants became separated by vast stretches of open or plantation land (Map 9). By 2007, local elephant populations in Rokan Hilir, Kerumutan, Koto Panjang, Bukit Rimbang Baling, Tanjung Pauh and Bukit Suligi had gone extinct, dropping the number of elephant pouches from 15 in 2003 to nine (Table 3, Map 9).

Table 3.—*Estimates of elephant numbers and distribution in Riau, Sumatra.*

Year	Elephant Population Estimate	Elephant Population Average Estimate	Distinct Elephant Pouches	Average Annual Population Loss	Surveys
1985	1067-1617	1342	11		Blouch and Simbolon, 1985[53]
1999	709	709	16	45	Dinas Kehutanan Provinsi Riau, 2002[54]
2003	353-431	392	15	79	Fadhli, N. 2004[55]
2007	174-246	210	9	46	Departemen Kehutanan, 2007[56]

The disappearance of elephants appears to be closely related to human–elephant conflict. Such conflict occurs where elephant forests have been replaced by fields or oil palm plantations, which then become alternate food sources for the animals. Four major mass poisonings of elephants have been reported. In 2002, 17 elephants were found poisoned near Mahato in Tapanuli Selatan, North Sumatra. In 2004, six elephants were poisoned in Rokan Hulu. In 2004, six elephants were poisoned in Kepenuhan near Mahato, and in 2006, another six elephants were poisoned in Mahato. Other such poisonings may have gone unnoticed.

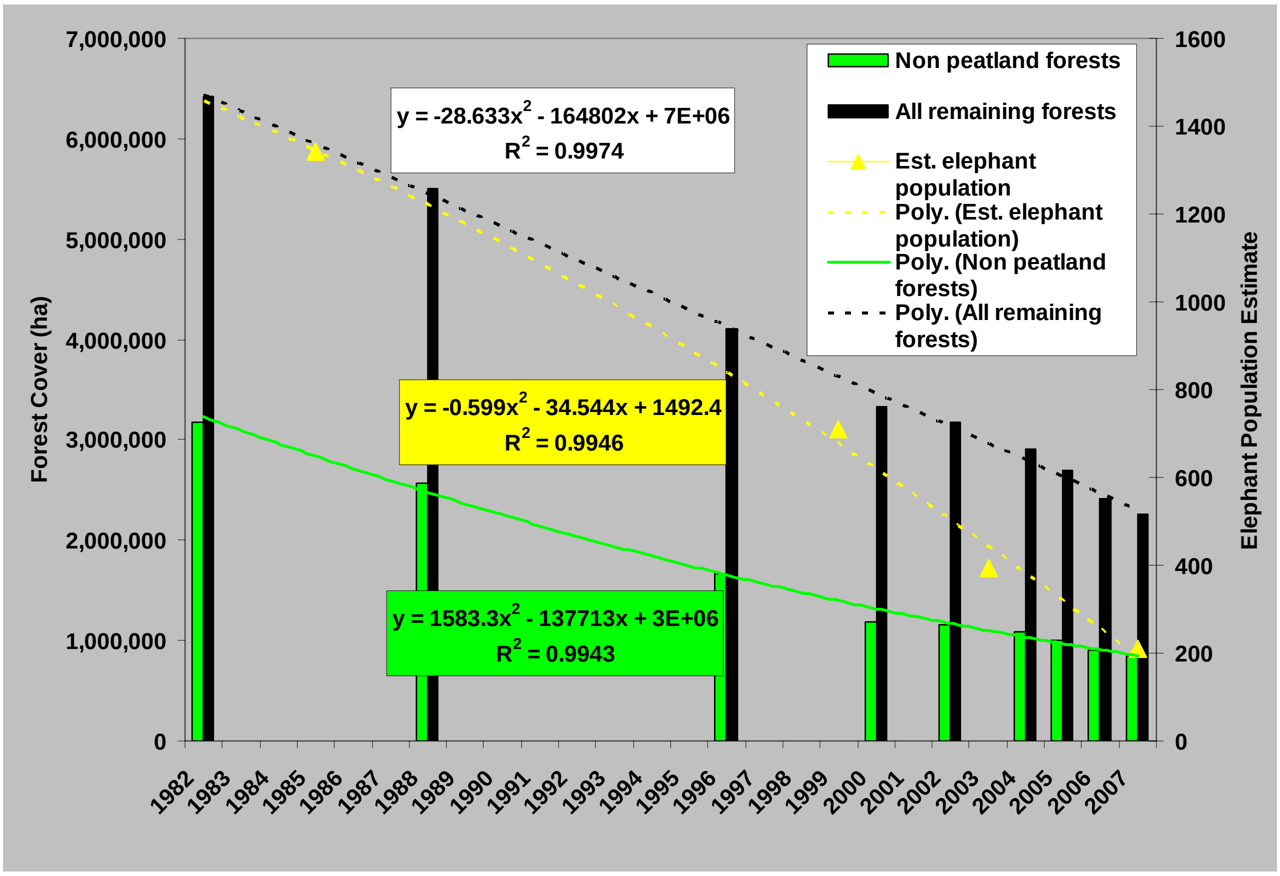


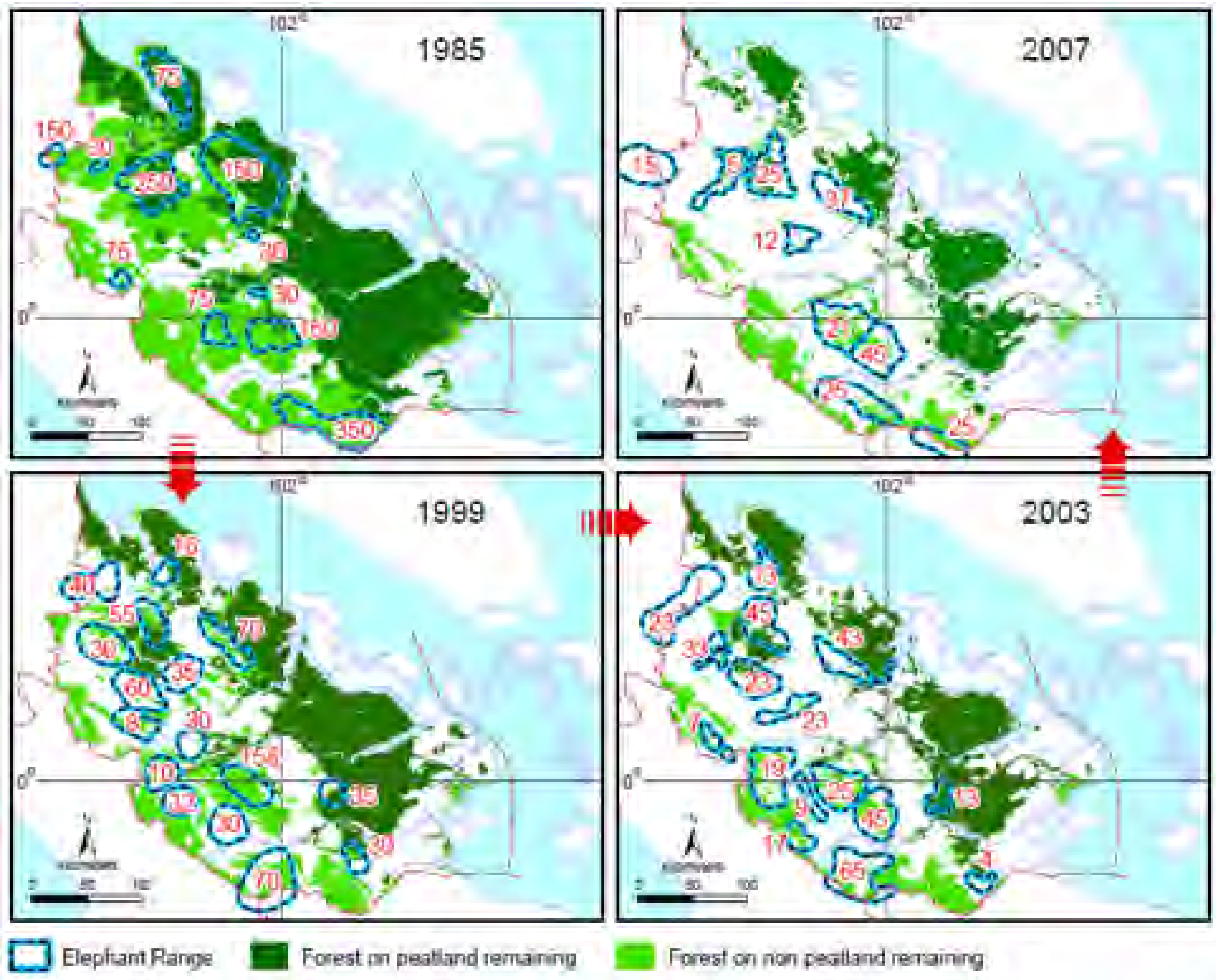
Figure 22.—*Forest cover, non peatland forest cover, and elephant population estimates in Riau 1982 to 2007.*

Additional evidence for conflict-related decline of elephants is the large number of animals captured by Government teams since 2000 (Table 4). WWF found evidence of at least 224 such captures; many more may have remained unnoticed (Table 4). WWF suspects that most captured elephants died at the capturing site, after the elephants were translocated to holding facilities, or after being released to the wild[57]. WWF and the provincial conservation authority have established so-called Elephant Flying Squads around the Tesso Nilo Forest (www.wwf.or.id/TessoNilo) that use trained, formerly wild elephants to try to protect fields and plantations from raiding elephants. These flying squads are the only serious attempt at human-elephant conflict mitigation anywhere in the province. Elsewhere, plantation owners and the authorities usually opt for elephants bothering them to "be removed" without employing less invasive conflict mitigation techniques that have proven effective elsewhere.

Table 4.—*Number of Government elephant captures in six districts in Riau 2000 to 2007 based on WWF investigations.*

District	2000	2001	2002	2003	2004	2005	2006	2007	TOTAL
Siak	-	-	-	-	3	-	-	-	**3**
Rokan Hulu	-	-	10	19	5	13	-	10	**57**
Pelalawan	-	-	-	-	1	-	1	2	**4**
Pekanbaru	-	-	-	1	-	-	2	-	**3**
Kampar	-	1	37	15	9	30	17	6	**115**
Indragiri Hilir	16	10	-	3	-	-	-	-	**29**
Bengkalis	-	-	-	-	7	6	-	-	**13**
TOTAL	**16**	**11**	**47**	**38**	**25**	**49**	**20**	**18**	**224**

We expect elephant numbers and pouches to continue to decline until all but two herds have gone extinct in Riau (Map 9). Some elephants may remain in the two largest remaining suitable elephant forests, Tesso Nilo and the flat and undulating slopes south and west of Bukit Tigapuluh National Park (Map 9). NGOs have repeatedly asked the Indonesian Ministry of Forests for the protection of these forests to keep Riau's elephants alive. They have not succeeded with their requests. The forests are in immediate danger of conversion by illegal encroachment and the pulp & paper industry, respectively.



Map 9 a to d.—*Peatland (dark green) and non peatland (light green) forest with approximate ranges of resident elephant herds in Riau, Sumatra.*

9.3 Status of Riau's Sumatran Tiger Population and Habitat

Sumatran tiger in Riau. © WWF Riau Tiger Survey

The Bali tiger has gone extinct; the Javan tiger has gone extinct. The Sumatran tiger is still alive, barely[58]. Its critical status is mainly due to the disappearance of its habitat[59,60]. Being Sumatra's largest province with, until recently, high forest coverage, Riau may have (had) more tigers than any other province. Yet, Riau's forests, the main habitat for tigers in Sumatra and also home to thousands of other species, are disappearing at an alarming rate.

We estimated Riau's tiger population based on known population densities and forest cover changes from 1982 to 2007. We then projected the development of Riau's tiger population until 2015 based on this report's "business as usual" and "implementation of draft land use plan" scenarios. For any given period, we identified potential tiger habitats based on the availability of forest patches with sizes deemed useable by tigers. We classified tiger patches, following the Tiger Working Group[61,62], into two categories: core habitats, defined as patches that can accommodate at least 5 tigers, and stepping stones, defined as patches of forests outside of core habitats with sizes greater than 10% of the minimum core habitat size. We assumed a density of 1 tiger/100 km^2, a value close to recent estimates from tiger studies in a variety of habitat types in Sumatra, especially Riau[63,64]. Assuming 1 tiger / 100 km^2, the minimum core habitat area would be 50,000 ha and the minimum stepping stone area 5,000 ha.

For 2007, the only year for which detailed land cover data for the whole province are available, we also predicted habitat availability for tigers by taking into consideration: (1) the availability of forest and non-forest land covers deemed to be used by tigers, and (2) the distance to roads as an indicator of disturbance. We assigned different values (scaled from 0 to 3, from very bad to good), according to the qualitative classification developed by Sanderson et al.[65] for different land covers. We operated "Log [distance to road]" and multiplied the result with the landcover scores. We classified the result into 10 equal interval classes including "no data" and considered the three classes with the highest score as "good habitat." Details on all models are in the full technical report[66]. In both models we assumed that:

- Natural forests are the only key habitat for tigers (mainly for the "forest only" model).
- Tiger densities are equal in different natural forest types.
- The ecological characteristics of the tiger remain constant over time.
- The response of tigers to habitat change remains constant.
- The density estimate we used is accurate and constant over time.
- Every patch with a size equal to or greater than a stepping stone is inhabited by tigers with equal density.

Tiger populations declined faster than forests. In 1982, Riau had 6,395,392 ha of core habitats and stepping stones, potentially supporting 640 tigers (Figure 23). The contiguity of forest in 1982 ensured that Riau's tiger populations were barely separated from each other (Map 7). Riau had only three core areas, two of which potentially supported 367 and 241 tigers, respectively. Tigers could be considered "self-sustaining" only in those habitats. By 2007, habitat availability had declined so much that the tiger population estimate dropped by 70% to 192 tigers. The tiger population estimate declined more sharply than forest was lost due to habitat fragmentation. By 2007, forest habitat had been fragmented into nine small core blocks, none of which could support more than 50 tigers (Map 7). However, core areas in southern and western Riau are still connected to forests in neighboring provinces. The viability of these populations therefore also is determined by the size of their habitats outside Riau.

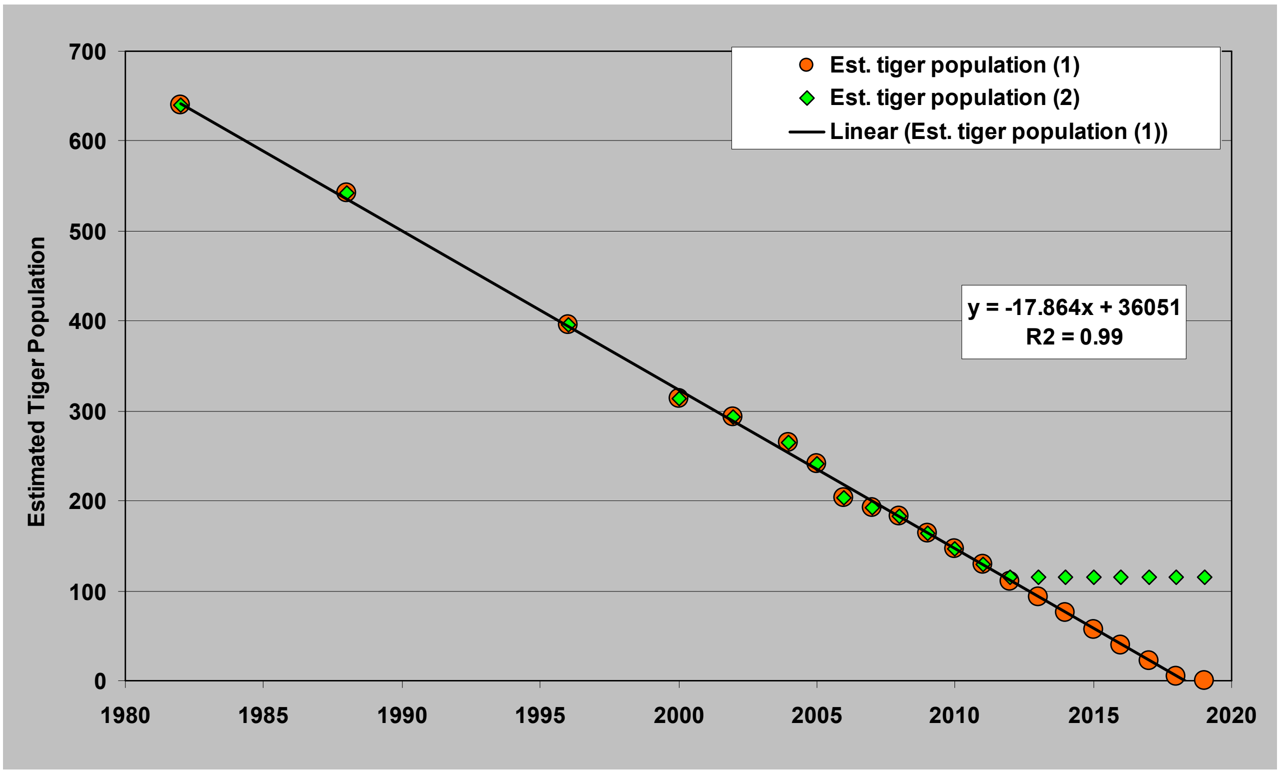


Figure 23.—*Tiger population estimates in Riau based on habitat availability from 1982 to 2007 and population projections based on two scenarios (2008 to 2019). Note: The formula shown is for the trendline for Scenario (1), excluding the projected data of 2008 to 2019.*

Adding potential marginal (non natural forest) tiger habitat to the models for 2007 changed tiger population estimates from 192 (forest cover model) to 278 (detailed land cover and disturbance model) (Table 5). However, detailed studies on tiger use of non-forested habitats are still ongoing and data are not yet available to reliably model such land uses.

Table 5.—*Comparison of "forest only" and "detailed land cover and disturbance" models for all Riau in 2007.*

	Models for 2007 Land Cover	
	"Forest Only"	"Detailed Land Cover & Disturbance"
# Core habitats	9	12
# Stepping stones	26	28
Total area of Core Areas and Stepping Stones (x 100 km^2)	191.8	277.6
Estimated Tiger Population	192	278

Table 6.—*Comparison of "Business as Usual" and "Implementation of Draft Riau Land Use Plan" scenarios for Riau in 2015.*

	Models for Predicted 2015 Land Cover	
	(1) "Business as Usual"	(2) "Draft Riau Land Use Plan"
# Core Habitats	4	8
# Stepping stones	5	12
Total area of Core Areas and Stepping Stones (x 100 km^2)	45.5	115.4
Estimated Tiger Population	46	115

While the "Land Use Plan" Scenario (2) is better than the "Business as Usual" Scenario (1), tigers are unlikely to thrive over the long-term in Riau under either scenario. Under Scenario (2), there will be 8 core habitats left by 2015, none of which can support more than 20 tigers. With a total area of core habitats and stepping stones of about 11,545 km^2, Riau would only be able to support about 115 tigers (Table 6). The reality could be much worse than the model predicts as an increase of conflict killings can be expected as humans intrude even further into tiger ranges. If the "Business as Usual" Scenario (1) prevails, all forests/habitat outside of the current nationally controlled protected areas will have disappeared by 2015. Under this scenario, there would only be four completely separated core habitats. Even the "stepping stones" predicted by this model would be unlikely to function as they would be too far from the core habitats. Forty-six tigers might survive, but possibly not for long.

To live, tigers require vegetation covers, abundant large prey, large areas to roam and hunt, and protection from being killed[67]. To survive long-term, a sub-population needs a minimum number of individuals; Sanderson et al.[68] considered that number to be not fewer than 100 individuals. Given the current habitat status for tigers in Riau, long-term viability of the populations can only be achieved if patches of core habitats are connected with functioning corridors and stepping stones.

10. REDD – Emissions

Based on very detailed land cover and land cover change information, we attempted to estimate CO_2 emissions caused by deforestation, forest degradation and peat decomposition for the Province of Riau over 17 years from 1990 to 2007. We are aware that these estimates may severely over- or underestimate the actual emissions because for many processes, detailed data on carbon stocks and carbon emissions (stock decrease) were not available. However, considering all possible errors and uncertainties we believe that the results indicate at least the order of magnitude of the emissions correctly.

Carbon sequestration by the growth of acacia and oil palm plantations that replaced natural forests were also calculated. Values for the TNBTK Landscape were extrapolated to the whole 8.3 million-hectare mainland of Riau. Emissions by peat fires were assessed in the TNBTK Landscape and in the whole Riau mainland from 1997 to 2007. Based on progress of deforestation of Riau's mainland from 1982 to 2007, we modelled two scenarios predicting development until 2015: Scenario (1) "Business as Usual" and Scenario (2) "Implementation of Riau's Draft Land Use Plan."

Clearance for acacia plantation development in Tesso Nilo, one of Riau's last remaining elephant forests. © WWF Indonesia

CO_2 emissions caused by land use change were approximated following a Stock-Difference Method that estimates the difference in total biomass carbon stock at time t_2 and time t_1, as described in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories[69]. The values for biomass carbon were based on research conducted within the GMES Forest Monitoring[70] program and a thorough literature review on biomass measurements of various tropical land covers for Indonesian and Southeast Asian forest ecosystems (Appendix 8 Biomass Literature). The carbon content of the biomass was set to 50% as recommended by the IPCC GPG guidelines 2006[71].

This methodology is an improved approach compared to TIER 1 level, which uses IPCC standard values as emission factors. Emission factors and carbon change assessment follow the TIER 2 level, which uses country-specific forest biomass value[72]. Remote sensing was used extensively (see Chapter 6) to assess area changes for all land covers and forest degradation as requested for TIER 3.

The biomass of different land covers was determined by calculating the median values of all published biomass values for a specific type. The biomass within specific forest types may vary regionally due to different growth conditions. These regional variations are to some extent contained in the statistical analysis of the published biomass measurements. More precise calculations of the variation in biomass within single land cover types would require extensive field measurements, forest inventory data and permanent sample plots in areas which are very difficult to access on the ground. In addition, the resolution of the Landsat satellite imagery is too low for more detailed assessments. These would require high resolution aerial imagery and 3D LIDAR data. For this region, no other satellite data are available for before 2000; assessments based on higher resolution data are therefore impossible.

Emissions were calculated assuming that all carbon lost through deforestation and forest degradation was released into the atmosphere. This assumption may lead to a slight overestimation, because an unknown amount of the harvested biomass was converted into furniture or paper.

CO_2 emissions from decomposing peat soil (peat oxidation) were based on a thorough literature review and long-term measurements of the University of Hokkaido in Borneo. CO_2 emissions from burning peat were based on published data and own long-term scientific studies (EUTROP, STRAPEAT and RESTOREPEAT projects).

Emissions from forest biomass burning were not considered, because there are virtually not data available on fuel loads, burn intensities, degree of fire damage and many other important parameters.

Uncertainties of CO_2 emission estimates

All calculations had to rely on assumptions and simplifications. Several sources of uncertainty lead to a propagation of errors. We did not add error margins to our estimations, as the level of error of our calculation component is not precisely quantifiable. Each component of our calculations contributes to the total uncertainty. However, considering and reflecting on all errors we are convinced that the order of magnitude of the emissions estimate are correct. Sources of error that contribute to the total uncertainty are:

1. Quality of the Landsat TM/ETM land cover and land cover change mapping (error of commission, error of omission, imprecise class definitions, transitions between vegetation types or degradation classes, mixed pixels etc.)
2. CO_2 emissions from deforestation and degradation (biomass variation over space, over species, degree of degradation etc.)
3. CO_2 emissions from peat decomposition (water level variation over space and time)
4. CO_2 emissions from peat burning (variation of burn depth, combustion etc.)

Regarding 1, land cover mapping was done by visual interpretation. The result strongly depends on the quality and experience of the interpreter. The landcover maps were produced by experienced Indonesian GIS and RS experts having worked in Riau and in the field for many years. Land cover maps were validated in the field and by aerial observation.

Regarding 2, Biomass values were based on a thorough literature survey. More detailed data is simply not available.

Regarding 3 and 4, CO_2 emission estimates followed state-of-the-art methods, long-term studies by the authors and thorough evaluation of the literature.

10.1 CO_2 Emissions from Deforestation and Degradation of Above Ground Biomass

10.1.1 Emissions in Riau's TNBTK Landscape 1990 – 2007

Using the data of the deforestation and degradation analysis in Chapter 6, we assessed biomass loss, corresponding carbon loss and CO_2 emissions. Each of the land use classes in the TNBTK Landscape and all of Riau in WWF's Land Cover Database was linked with the median value of the Above Ground Biomass (AGB) estimates (Appendix 8 Biomass Literature). The allocation was based on the description of the land cover and forest types provided in the reviewed literature. The sequestration by newly established acacia and oil palm plantations on converted land cover was calculated separately.

The complete carbon fixed in the biomass of the lost forests is considered to be released into CO_2. Carbon dioxide has a molar mass of 44 g/mol, whereas carbon has 12 g/mol. Thus, conversion from C to CO_2 is calculated as X C = X*3.66 CO_2.

Between 1990 and 2007, deforestation and forest degradation in the TNBTK Landscape resulted in a loss of 0.22 Gt C forest biomass carbon, from 0.40 Gt C in 1990 down to 0.18 Gt C in 2007, leading to CO_2 emissions of 0.81 Gt CO_2.

10.1.2 Emissions from Land Cover Change in Riau 1982 – 2007

Detailed land cover maps for the whole province were not yet available for the years before 2007. We therefore used Riau's 1982 forest/non-forest map to estimate the biomass carbon stock. We divided the 1982 forest cover into four forest types (dry lowland, peat, swamp and mangrove) and three canopy closure types (very open, medium open, rather closed) using the same relative proportion each type occupied in the 1990 Land Cover Database for the TNBTK Landscape. Our estimates for carbon stock decline and CO_2 emissions are conservative, because the general conditions of the forests (the amount of biomass) likely was higher in 1982 than in 1990.

Between 1982 and 2007, we estimated deforestation and forest degradation in Riau to have caused the loss of 0.57 Gt C forest biomass carbon, from 0.89 Gt C in 1982 to 0.33 Gt C in 2007[xi]. This caused CO_2 emissions of ca. 2.08 Gt (Figure 24). Deforestation and degradation of non peatland forest caused the release of 0.36 Gt C, equivalent to 1.31 Gt CO_2, 63% of the total estimated emissions.

10.1.3 Predicted Emissions in Riau 2007-2015

In Chapter 6.4, we projected the deforestation that may occur in all of Riau's peatlands and non peatlands between 2007 and 2015 based on two scenarios: "Business as Usual" and "Implementation of Riau's Draft Land Use Plan." Based on these models, CO_2 emissions from possible deforestation between 2007 and 2015 were estimated.

- Deforestation in Riau based on "Business as Usual" Scenario (1) could cause a biomass carbon stock loss of ca. 0.26 Gt C (from 0.33 Gt C in 2007 down to 0.07 Gt C in 2015), causing 0.94 Gt CO_2 emission (Figure 24).
- Deforestation in Riau based on "Land Use Plan" Scenario (2) could cause a total biomass carbon stock loss of 0.13 Gt C (from 0.33 C Gt in 2007 down to 0.19 Gt C in 2015), causing 0.49 Gt CO_2 emission[xii] (Figure 24).

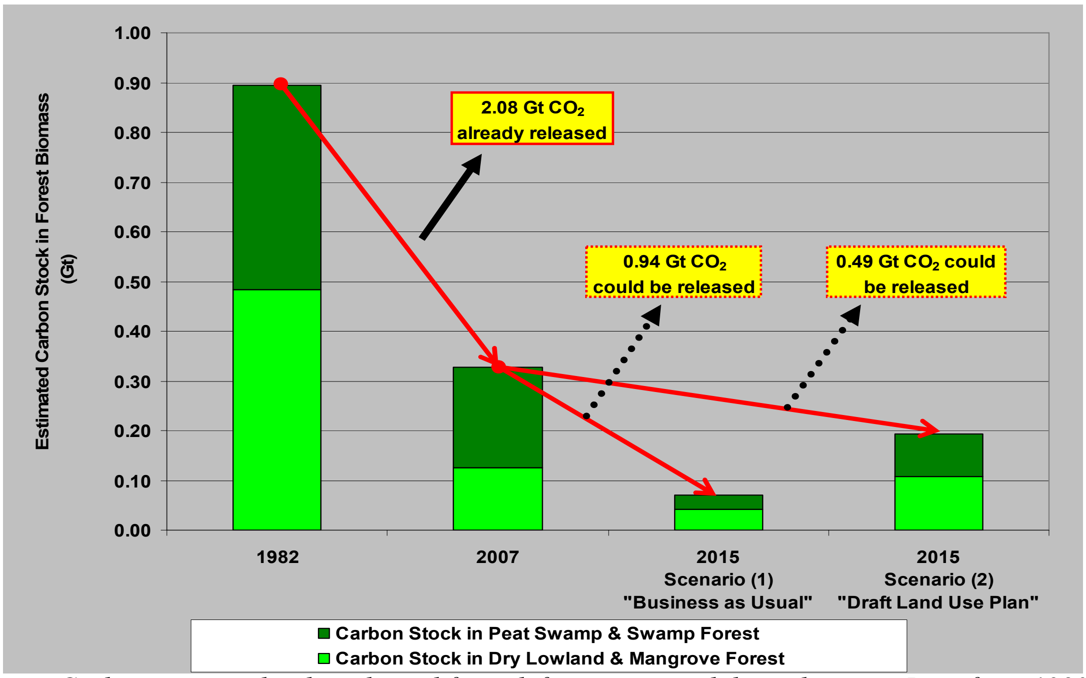


Figure 24.—*Carbon estimated to be released from deforestation and degradation in Riau from 1982 to 2007, and potential future emissions by 2015 based on two scenarios, "Business as Usual" and Implementation of Riau's Draft Land Use Plan."*

[xi] *All numbers are rounded.*
[xii] *All numbers are rounded.*

10.2 CO_2 Emissions from Decomposition and Burning of Below-ground Peat Biomass

Undisturbed peat swamp forests and tropical peatlands store and sequester huge amounts of carbon[73]. The biomass per hectare is 10-15 times higher than that of the forest biomass growing on the peat. Peat soils release huge amounts of CO_2 when deforested or burnt. Therefore it is important to include the peatland ecosystem in the emissions analysis.

If the vegetation cover is removed from peatlands, the carbon balance in peat soils is affected twofold: 1.) carbon sequestration by peat-forming plants is stopped and 2.) the peat soil starts to emit CO_2 due to the decomposition of soil organic matter (mainly peat decomposition). Sources of CO_2 emissions are also autotrophic respiration by roots and aboveground parts of the vegetation cover. Peat decomposition can occur naturally when the hydrology of the peat layer is disturbed. The carbon loss from peat decomposition usually exceeds the carbon sequestration of peat. The most dramatic emissions occur when the land use changes lead to burning of the peat. Both decomposition and fire are induced by human intervention such as drainage and land clearing.

10.2.1 Emissions from Peat Decomposition in Riau's TNBTK Landscape 1990–2007

If peatlands are developed for agriculture and plantations, they have to be drained to make the peat soil aerobic and the water less acidic. Then the drained peat layer undergoes quick decomposition through oxidation by microbial activity. Extended drought periods, as they regularly occur during El Niño episodes, lead to very low water tables (often more than 2 meter below the surface) thus accelerate the oxidation of the dry peat substrate. At the same time the peat becomes very susceptible to burning.

To estimate CO_2 emissions by peat decomposition, we determined emission values for different land covers that had replaced the 691,733 ha of peatland forests in the TNBTK Landscape between 1990 and 2007 (Table 7). Peat decomposition is closely related to drainage, i.e. the average depth of the water table below the peat surface. To estimate emissions we correlated measured peat decomposition values to different drainage regimes and land cover classes based on literature reviews and results of long-term studies in Sarawak[74] and Central Kalimantan (Table 7)[75] (Appendix 8 Biomass Literature). The emission values were averaged and assigned to the respective land cover conversion cases. Only published measurements that were taken in a comparable region and ecosystem and covering a time period of at least one year were selected to compensate for seasonal variations in groundwater levels. For established plantations, CO_2 emissions were considered cumulative.

Possible sources of error in the following calculations might be: 1.) The interannual variation of the groundwater level was not considered. This is especially true for El Niño and La Niña years in which emissions can be much higher or lower than usual. 2.) Most CO_2 measurements were taken on the soil surface, so the carbon sequestration by vegetation growth was not recorded. 3.) Published field measurements and our own measurements on CO_2 fluxes represent just a "snapshot" in time of drainage[76]. Often measurements were taken under completely different conditions, such as previous land cover change history and time passed since first drainage. No consistent and comparable data set currently exists. As far as possible we used only long-term and comparable measurements, but the standard deviation is high in (Table 7). Still, the method applied here is a reasonable starting point to estimate emissions from tropical peatlands.

Table 7.— *CO_2 emissions from peat (organic matter) decomposition (t CO_2/ha/year) related to different land covers. AG : Agriculture, PL : Plantation, CB: Cleared or Burnt forest (no trees standing).*

Land Cover Class	Land Use	Ave. Drainage	Mean	Median	SD	Max.	Min.
Acacia plantation	AG+PL	53	85	84	41	165	5
Oil palm plantation	AG+PL	53	85	84	41	165	5
Smallholder oil palm plantation	AG+PL	53	85	84	41	165	5
Cleared land	CB	21	29	26	9	48	22
"Waste" land	CB	21	29	26	9	48	22
Other land covers	CB	21	29	26	9	48	22

Based on Table 7 we estimated CO_2 emissions from peat decomposition in the TNBTK Landscape from 1990 to 2007 to be 0.11 Gt C, emitting a total of 0.43 Gt CO_2. 47% of the total release was caused by the conversion into oil palm plantations.

10.2.2 Emissions from Peat Burning in Riau 1997–2007

We analyzed the spatio-temporal occurrence of hotspots on peatlands between 1997 and 2007 (Figure 25). All hotspots were superimposed on the peatlands map published by Wetlands International and converted into burnt areas as described in Chapter 9. 1,107,605 ha of Riau's peatlands burnt at least once, 852,212 ha burnt more than once. Indonesian law protects peat deeper than 3 meters and forbids any development. Yet a large proportion of fires (57%) occurred on peat deeper than 2 meters.

To estimate CO_2 emissions caused by fires, we considered different scenarios of peat consumption by fire. For El Niño years, with their intense droughts the water table is usually lower than 1.50 meters. Thus burning is more intense and we assumed that 50 cm of peat burnt away[77]. For normal years, we assumed that 15 cm of peat burnt away on the average[78,79]. In total a peat volume of 6.314 km³ burnt, having a carbon content of 0.379 Gt C (Table 8). Peat fires in Riau could have released as much as 1.39 Gt CO_2 between 1997 and 2007.

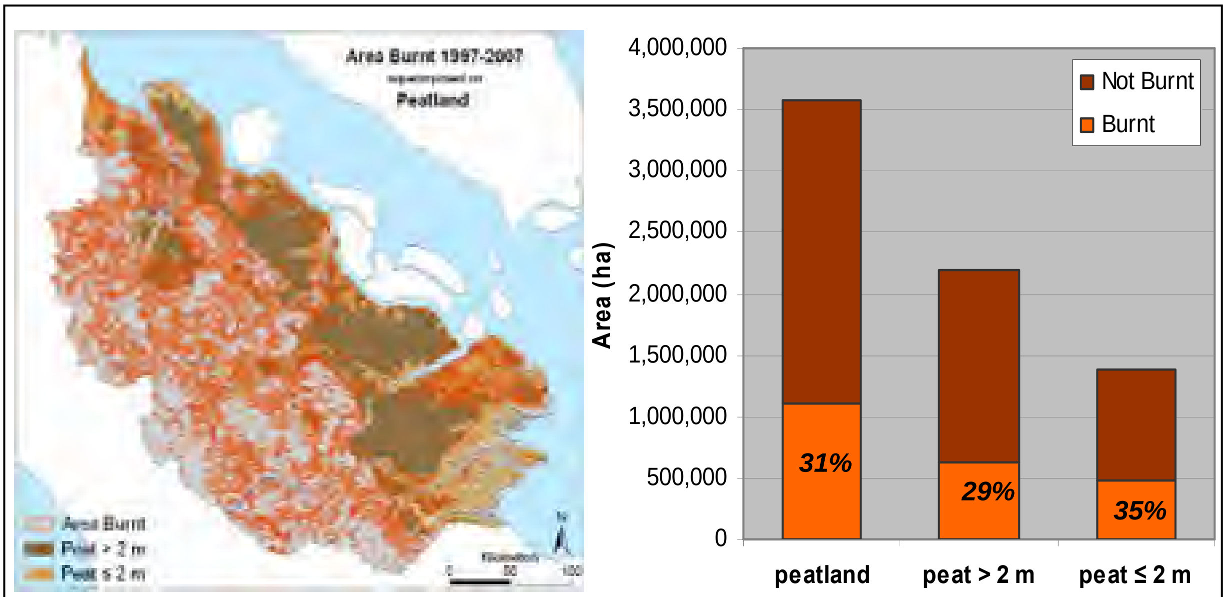


Figure 25.—*Area burnt in Riau between 1997 and 2007 superimposed on peatland map published by Wetlands International's. Deep peat (> 2 m, dark brown) and shallow peat (≤ 2 m, pale brown) are distinguished.*

Table 8.—*Amount of CO_2 released from peat fires 1997-2007.*

	Peat Area Burnt (ha)	Volume (km³)	Carbon content (Gt) (60 kgC/m³ of peat)	CO_2 emission (Gt)
1997-2007	1,959,817	6.314	0.379	1.39

10.3 Total CO_2 Emission in Riau's TNBTK Landscape 1990-2007

CO_2 absorption values of acacia plantations, oil palm plantations, smallholder oil palm plantations and "waste" lands that replaced the forests between 1990 and 2007 are shown in Table 9. Country-specific biomass values were used for the CO_2 absorption (Appendix 7 Biomass).

Acacia plantations and oil palm plantations that replaced natural forests absorbed 0.13 Gt of CO_2 (Table 10). Acacia plantations sequestered 0.06 Gt atmospheric CO_2 and oil palm plantations 0.07 Gt CO_2.

Table 9.—*CO_2 absorption values of plantations replacing natural forest in Riau's TNBZK landscape (1990 – 2007).*

	Acacia Plantation	Oil Palm Plantation	Total
CO_2 Absorption (CO_2/ha)	190.32	199.47	-
Total Area (ha)	345,856	333,417	679.273
Total CO_2 Sequestration (Gt)	0.06	0.07	0.13

We did not estimate potential sequestration of forests. Whether pristine forests sequester carbon, are neutral or even emit CO_2 is still under discussion in the scientific community. A recent publication states that primary tropical rain forests sequester CO_2, and thus are a carbon sink[80]. However, the prevalent opinion among scientists is that primary rainforests are a climax vegetation, meaning a plant community that is in equilibrium with its environment, i.e. carbon sequestration equals carbon emissions. We also did not estimate CO_2 emissions from burning of aboveground biomass because of too many uncertainties, i.e. amount of fuel, burn severity, forest biomass, etc. Therefore, the calculated net emission can be considered as conservative, i.e. an underestimate. Sequestration by coconut and rubber plantations was also excluded,

By 2007, 1.53 Gt of CO_2 had been released (Table 10):

Release = (Emissions from Deforestation + Forest degradation + Peat decomposition + Peat fire) – (Sequestration by replacing acacia & oil palm plantations)

Note: emissions from peat burning were only assessed from 1997 to 2007, because no records of fire hotspots exist for the time before 1997.

Table 10.—*Summary of carbon budget in the TNBTK Landscape between 1990 and 2007 based on CO_2 emissions from deforestation, forest degradation, peat decomposition, peat fire (since 1997 only) and CO_2 sequestration by replacing land covers*[xiii].

CO_2 Emissions and Sequestration ($Gt\ CO_2$)	1990 – 1995	1995 - 2000	2000 - 2005	2005 - 2007	1990 - 2007
Emission by deforestation	0.17	0.31	0.14	0.02	0.64
Emission by forest degradation	0.03	0.05	0.04	0.04	0.17
Emission by peat decomposition	0.02	0.11	0.20	0.10	0.43
Emission by peat fire	-	0.12	0.18	0.12	0.42
Total emissions	0.23	0.59	0.56	0.28	1.66
Sequestration by acacia & oil palm plantations	-0.02	-0.06	-0.04	-0.01	-0.13
Net emissions	0.21	0.53	0.52	0.27	1.53

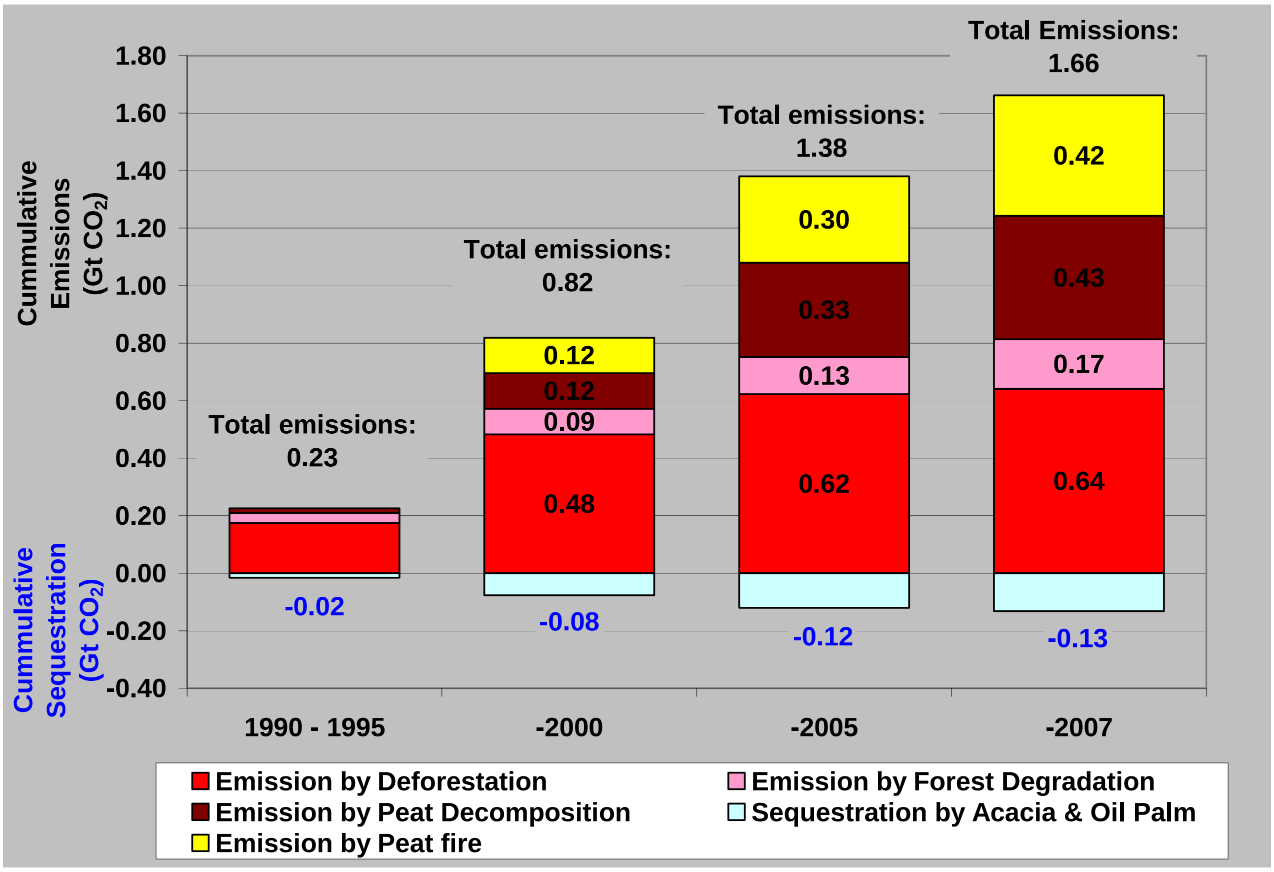


Figure 26.—*Carbon budget of the TNBTK Landscape between 1990 and 2007. CO_2 emissions by deforestation, forest degradation, peat decomposition, peat fire (1997 – 2007) and CO_2 sequestration by acacia & oil palm plantations were considered. Discussion of uncertainties: see Introduction to Chapter 11.*

[xiii] *All numbers are rounded.*

10.4 CO_2 Emissions in Riau 1990-2007

CO_2 emissions for the whole province were estimated by extrapolating the result for the TNBTK Landscape, assuming that the same land cover change processes and emissions from peat occurred outside the Landscape.

Total carbon dioxide emissions for Riau amounted to 3.66 Gt CO_2, composed of 1.17 Gt CO_2 from deforestation, 0.32 Gt CO_2 from forest degradation, 0.78 Gt CO_2 from peat decomposition, and 1.39 Gt CO_2 from peat burning (from 1997 onwards only) (Figure 27). The emissions from peat burning were not extrapolated but directly calculated using the hotspot data, which was available for the whole province.

During the same period 0.24 Gt CO_2 sequestered by pulpwood and oil palm plantations that replaced natural forests. Net emissions were thus 3.42 Gt CO_2.

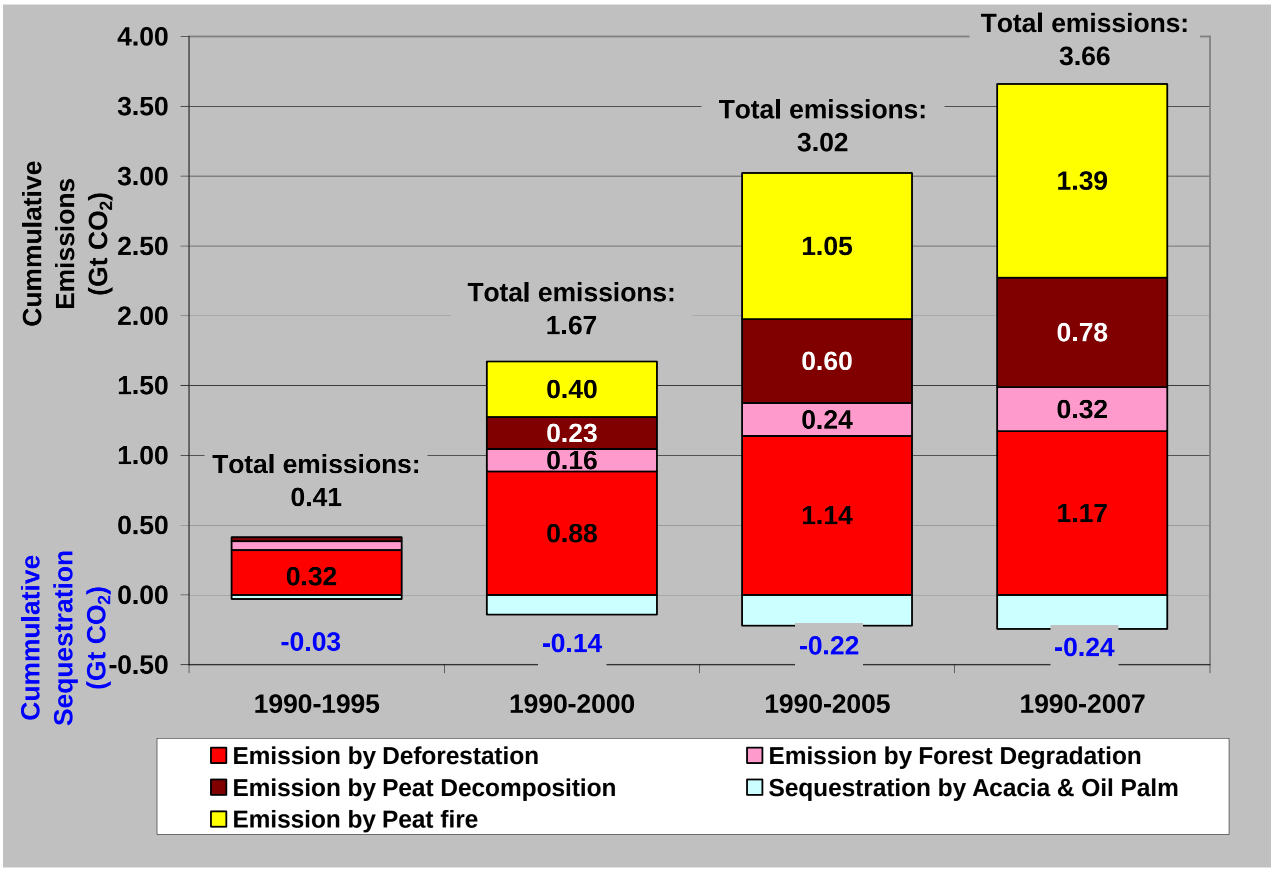


Figure 27.—*Carbon budget for the whole Province of Riau between 1990-2007. Discussion of uncertainties: see Introduction to Chapter 11.*

Over the last 17 years, Riau's average emissions from deforestation, forest degradation, peat decomposition and peat fires accounted for 0.22 Gt CO_2 per year.[xiv] This is equal to 79% of Indonesia's emissions from fossil fuels in 2004[81].

For comparison: Riau has emitted every year more CO_2 than the Netherlands (122%), more than half that of Australia (58%), more than a third that of United Kingdom (39%) and a quarter that of Germany (26%)[82] (Table 11).

[xiv] Sequestration by replacing plantations is not considered here. Pulpwood and oil palm plantations sequester approximately 0.014 Gt CO_2 per year.

The amount of total anthropogenic carbon dioxide emissions including emissions/removals from LULUCF reduced to meet the Kyoto reduction target in Germany was 0.17 Gt CO_2 per year from 1990 to 2005[83]. Radical political and economical reforms as well as huge investments of several billion US dollars were necessary to achieve Germany's Kyoto goal. The province of Riau alone produces more carbon dioxide per year than Germany, the fourth largest industrial nation, saves.

0.22 Gt CO_2 is also equivalent to 24% of the collective annual GHG emissions reduction target by the Annex I countries in the first commitment period of 2008-2012[84] (Table 11).

Reducing CO_2 emissions globally would be far more effective if investments were not only allocated to reduce emissions in industrial countries but also to reduce emissions by avoiding deforestation in developing tropical countries such as Indonesia. An established REDD mechanism and REDD-like voluntary programs could significantly contribute to reduce global CO_2 emissions and thus mitigate climate change and global warming.

Table 11.—*Comparison of Riau's average annual emissions from deforestation, degradation, peat decomposition and peat fires between 1990 and 2007 with CO_2 emissions of selected other countries*[85,86,87].

	Annual CO_2 Emissions (Gt)	Riau's Annual Emissions Relative to Others
Riau: all emissions from deforestation, forest degradation, peat decomposition & peat fire: 3.66 Gt CO_2 (1990 – 2007)	0.22	100%
Indonesia: energy sector emissions (2004)	0.28	79%
Australia: total CO_2 emissions including emissions/removals from LULUCF (2005)	0.38	58%
Germany: total CO_2 emissions including emissions/removals from LULUCF (2005)	0.84	26%
Netherlands: total CO_2 emissions including emissions/removals from LULUCF (2005)	0.18	122%
United Kingdom: total CO_2 emissions including emissions/removals from LULUCF (2005)	0.56	39%
European Community: total CO_2 emissions including emissions/removals from LULUCF (2005)	3.16	7%
Kyoto Protocol Annex I countries: collective annual GHG emissions reduction target in the first commitment period (2008-2012) (5% from 1990 levels in CO_2).	0.93	24%

11. Conclusions

Riau's elephants are going extinct – fast.

Over the last quarter century, 84% of Riau's elephants died; perhaps as few as 200 survive in Riau today. Their death is directly related to deforestation. The province lost 65% of its forest cover during the same years, more than 4 million hectares. The elephants died because their habitat was replaced by plantations and became so fragmented that they got into ever-increasing conflict with people. Four mass poisonings of elephants have been recorded in or near oil palm plantations since 2002 alone. Hundreds of elephants may have died or "disappeared" after being captured when feeding in oil palm plantations or fields that, often illegally, had replaced their forests.

Elephant family deliberately poisoned after feeding in cropland that had replaced their forests in Riau. © WWF Indonesia.

Skull of poached tiger being traded. © Tariq Aziz

Tigers are disappearing as fast as elephants. Both species' population estimates are dropping faster than even the forest cover, likely an effect of the extreme fragmentation of their habitats. Riau's forests have become so fragmented that today only two forests remain that may offer enough habitat for elephant populations, Tesso Nilo and the rolling hills south and west of Bukit Tigapuluh National Park. The former is being heavily encroached by immigrants from another province without land owners or Government enforcing the law and stopping the encroachment. The latter was just given to Riau's pulp & paper industry for clearcutting; major logging highways are being built right up to the national park boundary by companies associated with Asia Pulp & Paper (APP)[88] as this report is being written. Not only are these forests essential for elephants, but Bukit Tigapuluh was classified as global priority tiger habitat in 2006 and now contains an orang utan population that is spreading fast. All will lose their habitat in the large-scale clearcutting that is to begin soon. NGOs have long asked Government to protect these areas by expanding these neighboring national parks. Government has not done so.

Orang Rimba children, an indigenous people who live solely in natural forest, encounter a logging road near Bukit Tigapuluh National Park. © WWF Indonesia

Riau has suffered one of the most dramatic deforestation rates of any province in Indonesia in recent years.

We estimate that over the last quarter century, 0.57 Gt of forest biomass carbon was lost through deforestation to cause 2.08 Gt of CO_2 emissions. Until about 2000, companies destroyed some of the most plant diverse forests on Earth. As fewer and fewer of these dry lowland forests became easily accessible, companies switched to Riau's peat forests. These peatlands store more carbon per hectare than any other ecosystem. Already Asia Pacific Resources International Holdings Limited (APRIL) has cut one of the largest and deepest of Riau's peatlands, Kampar Peninsula, in half with a major logging highway, significantly altering its hydrology and drawing encroachment and illegal logging. And APP followed suit in 2007, building a logging highway with deep drainage canals into the primary dome of the Kampar peat, draining it right from its heart.

Fires in an illegally encroached area inside proposed extension of Tesso Nilo National Park, Riau. © WWF Indonesia.

Peat swamp forests and tropical peat are at the center of the discussions on global climate change because they release huge amounts of CO_2 when deforested or burnt. Peat swamp forests protect the fragile peat soils below and prevent decomposition of the peat. If undisturbed, tropical peatlands are an important carbon sink as they sequester significant amounts of CO_2. We estimate that through deforestation and loss of peat, Riau may have emitted as much as 3.66 Gt of CO_2 since 1990. Fifty-nine percent of that was from decomposition of peat soil and peat fires only. Riau's average annual deforestation related CO_2 net emissions were equal to 50% of Australia's total annual emissions in 2005, 68% of Indonesia's total annual emissions from the energy sector in 2004, and were higher than the total annual CO_2 emissions of the Netherlands. Carbon sequestration by vegetation re-growth and acacia and oil palm plantations that replaced the forest was only 0.39 Gt CO_2.

Some of the emissions happen unrecognized and slowly as drained peat becomes decomposed by bacterial activity. Other emissions are visible as haze across Southeast Asia. Every year when the rains stop, Riau goes up in flames, with uncontrolled wildfires burning the logging debris and consuming up to 50 cm of the desiccated peat. Between 1997 and 2007, more than 72,000 active fires have repeatedly created Riau's infamous haze that hangs so heavily over the province and neighboring Singapore and Malaysia. Thirty-one percent of Riau has already burnt once; many areas have burnt two or more times. These recurrent fire disasters are a severe threat to rainforest ecosystems because they impede forest regeneration and eventually convert forest ecosystems into grasslands. How much more carbon will go up in smoke by the unsustainable practices of the plantation industries? Satellite images show that only national parks and large, rather intact contiguous peat land forests in Riau have seen few fires. As long as forests are intact, fires don't start and the carbon stays locked up. When the forests are opened the fires start.

Only two events appear to have reduced the rate of deforestation in Riau. First came the debt default of Riau's pulp & paper industry in the early 2000s, during which APP defaulted on US$13.9 billion, the biggest bankruptcy in Asia at the time. Next came in-depth police investigations into illegal logging and forest conversion by Riau's pulp & paper industry. Not for a long time have Riau's roads been so free of logging trucks as during 2007.

APP's new logging highway cutting into natural peatland forest, Kampar Peninsula, Riau. © WWF Indonesia

Of the forests converted by the pulp industry in the TNBTK Landscape, 96.2% were of high quality, with canopy closure of over 40%. That is despite the fact that Government regulations only allowed the establishment of pulpwood plantations on "waste" lands: lands that are barren, grasslands, bush, or very degraded forests. By 2007, 28.7% (1.1 million hectares) of 1982 forest had been converted to or cleared for oil palm plantations, many of them with high canopy closure. The industry had started the province's forest conversion boom and had always been leading Riau's deforestation. But the situation has changed; now more forest is converted to pulpwood plantations than to oil palm plantations. But does it matter? All the wood from the forest clearings has gone to the same pulp mills. Their wood purchases have been funding the development of oil palm plantations. Not surprisingly, both of Riau's pulp mills are run by conglomerates, Sinar Mas (parent company of APP) and Raja Garuda Mas (parent company of APRIL), which also own major palm oil companies.

Both industries by and large respected nationally controlled protected areas and did not convert much forest in them. The biggest threat to the nationally protected areas were smallholder oil palm plantations that encroached them more than any other land use. Forests in locally protected areas (Kawasan Lindung) were less well-protected and experienced major deforestation for pulpwood plantations.

The current drop in deforestation in Riau due to the police investigations may be short-lived though; Riau's pulp & paper industry now "owns" about 25% of Riau's mainland and has already converted about 950,000 hectare of forest since 1982. Models show that "business as usual" will clear most forest in Riau outside of nationally controlled protected areas. They would become little islands in an ocean of pulpwood and oil palm plantations. Government regulations require that pulpwood plantations protect some natural forest, but the industry's record is mixed. It remains to be seen how the industry responds to calls for the protection of all forests with high conservation values in their concessions in the years to come. Models show that even the implementation of the 2007 draft Riau land use plan would see the pulp industry driving deforestation, mostly of forests with high canopy closures on peatlands. The models see the industry converting forests far beyond the capacity needs of their existing mills. Already companies are shipping unprocessed plantation fibre to mills in China instead of using it in their Indonesian mills. The models support the persistent rumours of major expansion plans of the industry likely to drive the deforestation of many new areas, and not only in Riau but also in neighboring Jambi Province, in Kalimantan and Papua. The Ministry of Forestry is opposing the police operations in Riau. The Ministry suggested in 2004 that pulpwood concession holders accelerate their pulpwood plantation development and finish all their forest clearing by the end of 2009[89]. This originally sounded like interesting news as it appeared to mean that after 2009 no more natural forest wood could be supplied to produce pulp and paper. However, NGOs became increasingly concerned that this Decree has, in reality, been accelerating natural forest clearance in Riau and beyond. The process to receive pulpwood concessions became easier and concession licenses began being issued without due diligence for environmental and social issues.

Canal opened for acacia plantation development and natural peatland forest waiting to be cleared in the background, Riau. © WWF Indonesia

WWF fears that large areas of natural forests in Riau and other parts of Indonesia would have to be cleared to meet the national pulpwood plantation targets of 5 and 9 million hectares by 2009 and 2014. Where will all the barren land, grasslands, bush, or very degraded forests be found to accommodate such large-scale developments?

Indonesian forestry policy is striving to balance forest resource uses for commercial, restoration and conservation purposes. In the last 10 years, more and more emphasis has been given to conservation and the development of forest plantations. This is a response to declining resources from natural forests for the timber-based industry (mostly for plywood and sawn timber) as well as an accelerated rate of deforestation. Government, therefore, stresses efforts to restore degraded forest, conserve important remaining forests, and develop forest plantations to ensure sufficient fiber supplies for the timber-based industry while decreasing pressure on natural forests. However, deforestation in many areas is not decreasing because of still-huge demand for fiber by the pulp & paper industry that cannot be satisfied by plantations.

Government Regulation No. 34 of 2002 was very careful in the way it regulated forest plantation development in natural forests. The Regulation allowed plantations only to be developed in bare land, grassland and shrubland. New Government Regulation No. 6 of 2007 replaces Regulation No. 34 and removes this clause, specifying that forest plantations can be developed anywhere in "unproductive" forests. Our analysis has shown that in Riau, most forest plantations replaced natural forests, whether they were productive or unproductive, even with Government Regulation No. 34 of 2002 in full effect. With the new regulation allowing unproductive natural forests to be converted for plantations, forest conservation faces even greater challenges. Who will decide which forest is productive and which is not? And on what criteria?

Canal opened in the middle of dense canopy peatland forest in Riau, first to drain the soil and later to transport natural forest timber cleared for acacia plantation development. © WWF Indonesia

But the new regulation also allows concession licenses to be issued for ecosystem restoration on degraded land. Payment schemes for environmental services, including carbon trading, can be developed for such ecosystem restoration concessions. The new regulation also allows payment schemes for environmental services to be developed in production forest concessions (for both natural forest selective logging practices and plantation development). Concession holders can now market two commodities: timber from the extractive part of the concession and environmental services from the conservation part of the concession. Global demand exists for carbon trading from natural forests in the spirit of the REDD concept. Carbon from plantations is not eligible for trade.

This could actually provide a good future for Indonesia's forest industry, provided more policies are issued to encourage the commercialisation of environmental services. If the profits from marketing environmental services are comparable to those of marketing the timber, we could see more forest protected by concession holders. This might be the case with Riau's carbon-rich peatland forests. The potential value of trading protected carbon stocks of these forests may be comparable or even better to many other conventional uses of natural forests.

12. Appendices

Appendix 1.—*Data sources for forest cover maps. (The original sources did not distinguish forests on peat soils versus dry soils. We mapped those by overlaying the original maps with the peat areas defined by Wetlands International.) See also Appendix 5 for list of satellite images used.*

Year	Author	Data:
1982	World Conservation Monitoring Centre, UNEP	Landsat MSS images (60m resolution) and REPPPROT (1:250,000).
1988	Indonesian Ministry of Forestry	Landsat MSS images (60m resolution).
1996	Indonesian Ministry of Forestry	Landsat TM (30 m resolution)
2000 – 2006	WWF Indonesia	Landsat ETM images (30m resolution)
2007	WWF Indonesia	Landsat ETM images (30m resolution). Forest cover was calculated pooling 13 classes of “Natural Forest” (High Class Codes 1.1, 1.2 and 1.2.3, except Young Mangrove) of the WWF GIS Riau Land Cover Database (Appendix 4). Logging roads and other small non-forest areas were mapped in detail and excluded from forest cover.
2015	WWF Indonesia	Predicted by applying Draft Riau Land Use Plan (Appendix 6) to 2007 land cover.

Appendix 2.—*Nationally recognized protected areas in Riau and forest cover in or close to their respective year of declaration, depending on the year for which a forest-non forest cover map was available.*

Name	Type of License	License Issued by	License Number	Date of Declaration	Size of Areas on map inside the provincial boundary (Ha)	Forest cover after declaration, based on forest-non forest cover maps		
						Year	ha	%
Sungai Dumai	Recreational Park	Governor of Riau	85/1/1985	5/25/1985	3531.6	1988	2348.0	66.5%
Bukit Batu	Wildlife Sanctuary	Forestry Dept.	173/Kpts-II/1986	6/6/1986	23412.8	1988	21555.6	92.1%
Giam Siak Kecil	Wildlife Sanctuary	Governor of Riau	342/XI/1983	11/3/1983	85076.0	1988	70796.9	83.2%
Balai Raja Duri	Wildlife Sanctuary	Agriculture Dept.	173/Kpts-II/1988	6/6/1988	16722.6	1988	12407.0	74.2%
Sebanga	Elephant Training	Governor of Riau	387/VI/1992	6/29/1992	5842.2	1996	364.8	6.2%
Danau Pulau Besar/Bawah	Wildlife Sanctuary	Agriculture Dept.	848/Kpts/Um/8/1980	11/25/1980	25852.7	1982	24578.8	95.1%
Sultan Syarif Kasyim Minas	Grand Park Forest	Forestry Dept.	349/Kpts-II/1996	6/5/1996	6146.1	1996	2509.1	40.8%
Tasik Belat	Wildlife Sanctuary	Forestry Dept.	173/Kpts-II/1986	6/6/1986	2229.7	1988	2059.7	92.4%
Tasik Besar /Tasik Metas	Wildlife Sanctuary	Forestry Dept.	173/Kpts-II/1986	6/6/1986	2587.4	1988	2100.4	81.2%
Tasik Serkap	Wildlife Sanctuary	Forestry Dept.	173/Kpts-II/1986	6/6/1986	6084.9	1988	5667.7	93.1%
Bukit Bungkuk	Game Reserve	Forestry Dept.	173/Kpts-II/1986	6/6/1986	12865.0	1988	11533.8	89.7%
Kerumutan	Wildlife Sanctuary	Agriculture Dept.	350/Kpts/Um/6/1979	6/6/1979	96111.4	1982	96111.4	100.0%
Bukit Rimbang Baling**	Wildlife Sanctuary	Governor of Riau	149/V/1982	6/21/1980	133288.1	1982	133138.9	99.9%
Bukit Tigapuluh**	National Park	Forestry Dept.	539/Kpts-II/1995	10/5/1995	100585.5	1996	91143.7	90.6%
Tesso Nilo	National Park	Forestry Dept.	255/Menhut-II/2004	7/19/2004	38231.0	2004	28007.6	73.3%
				Total area	558567.0		504323.5	90.3%

Appendix 3.—*Data sources used to support image classification for land cover analysis and identification of land users.*

Type of Data	Source	Notes
River	Bakorsutanal Topography map	Scale 1 : 50.000
Road Network	Bakorsutanal Topography map	Scale 1 : 50.000
	WWF Surveys 2000 - 2005	GPS track
Settlement	Bakorsutanal Topography map	Scale 1 : 50.000
	WWF Field Surveys 2000 - 2005	GPS record of Center of village
Conservation Area	Riau Forestry Service, MoF, Riau BKSD (Riau Conservation Agency)	2004 data
Industrial Forest Plantation Concession (HTI)	Riau Forestry Service	2004 data 2005 data
Oil Palm Concession	Riau Plantation Service	2004 data
Mining Concession (oil)	Caltex Prima Indonesia	2000 data
Riau Land-use Plan 1994–2005	Riau Provincial Government (Bapeda)	Scale 1 : 250.000, 1994 data
Range of Peatland	Wetland International & CIDA	Scale 1 : 250.000, 2002 data
Concession map	APRIL	2006 data
Concession map	APP	2005 data

Appendix 4.—*Classification and Levels of Difficulty to Identify Land Cover Types on Landsat ETM-7 in Tesso Nilo-Bukit Tigapuluh-Kampar Landscape (***** Easy / **** Rather Easy / *** Moderate / ** Rather difficult / * Difficult).*

No.	Land Cover Name	Level of Difficulty to Identify	Group Name for Deforestation & Degradation Driver Analysis	Biomass Value from Literature for Emission / Sequestration Calculations
I.	**SPONTANEOUS VEGETATION TYPES**			
1	**Natural Forest**			
	Dry Land			
1	Dry Lowland Forest rather closed canopy	*****	Same as the Land Cover Name	367
2	Dry Lowland Forest medium open canopy	*****	Same as the Land Cover Name	264
3	Dry Lowland Forest very open canopy	****	Same as the Land Cover Name	73
4	Dry Lowland Forest on Metamorphic Rock	***	Same as the Land Cover Name	Not present in Riau
	Swampy Area			
5	Peat Swamp Forest rather closed canopy	*****	Same as the Land Cover Name	281
6	Peat Swamp Forest medium open canopy	****	Same as the Land Cover Name	234
7	Peat Swamp Forest very open canopy	****	Same as the Land Cover Name	62
8	Swamp Forest rather closed canopy	****	Same as the Land Cover Name	220
9	Swamp Forest medium open canopy	***	Same as the Land Cover Name	173
10	Swamp Forest very open canopy	***	Same as the Land Cover Name	44
11	Mangrove Forest rather closed canopy	***	Same as the Land Cover Name	187
12	Mangrove Forest medium open canopy	***	Same as the Land Cover Name	140
13	Mangrove Forest very open canopy	***	Same as the Land Cover Name	37
14	Young Mangrove	**	Same as the Land Cover Name	37
2	**Secondary Re-growth (Dry & Wetland)**			
15	Forest Re-growth (Belukar)	****	"Waste" land	37
16	Shrubs (Semak/Belukar Muda)	*		37
17	Forest Re-growth on Swampy	***		37
18	Shrubs on Swampy	***		37
19	Swamp Grasses/Fernland	**		37
20	Overgrowing Clear cut-Shrubs	**		37
21	Grassland	**		37

II.	**CULTIVATED TYPES AND PLANTATIONS**			
22	Young Acacia Plantation	*	Acacia plantation	104
23	Acacia Plantation	*****		104
24	Paraserianthes Plantation	**	Other land cover	0
25	City Park (Hutan Kota)	**		0
26	Young Oil Palm Plantation	*	Oil palm plantation	109
27	Oil Palm Plantation	*****		109
28	Small Holder Oil Palm	**	Small holder oil palm plantation	109
29	Small Holder Young Oil Palm Plantation	*		109
30	Mosaic of Small Holder Oilpalm and Rubber	*		109
31	Rubber Plantation	****	Other land cover	0
32	Small Holder Rubber	**		0
33	Coconut Plantation	****		0
34	Mixed Agriculture	****		0
35	Mixed Garden	****		0
36	Paddy Field	****		0
III.	**NON VEGETATION TYPES**			
37	Cleared, for Acacia Plantation	*	Acacia plantation	0
38	Cleared, for Oil Palm Plantation	**	Oil palm plantation	0
39	Cleared	****	Cleared	0
40	Sand Mining	**	Other land cover	0
41	Burnt	***		0
42	Sediment	****		0
43	Water Body	*****		0
44	Town	*****		0
45	Settlement	***		0
46	Factory	***		0
47	Airport	****		0
48	Fishpond	***		0
49	Mill-Oil	***		0
50	Cloud or no information	*****		0

The biomass specifications used for this study were taken from different scientific literature sources. "Other land cover" included Non-vegetation types, like "Sediment" or "Water Body", but also vegetation types like "Mixed Agriculture" or "Rubber Plantation". As the major goal of the study was to analyse the impact of palm oil and pulp and paper industry on deforestation and carbon balance, the potential sequestration of other land cover types was not assessed. For plantations (red) a lower value was assumed to account for the different growing stages of the life cycle of a plantation. All plantations are in transition from "Cleared" to "Grown-up plantation". For oil palm plantations we assumed a relationship of 0.8 of grown-up to cleared oil palm (oil palm has a life span of app. 25 years) and 0.6 for fast-growing acacia plantations with a life span of 5 – 12 years, depending on the soil type. In Appendix 7 and 8, all biomass specifications plus their corresponding literature references are shown.

Appendix 5.—*Satellite images used for all Riau forest cover in TNBTK landscape land cover analysis.*

Forest Cover Analysis	Land Cover Analysis	Satellite	Path/Row	Date of Acquisition
2007	2007	Landsat ETM	125/060	August 03, 2006
2007	2007	Landsat ETM	125/060	April 16, 2007
2007	2007	Landsat ETM	126/059	August 26, 2006
2007	2007	Landsat ETM	126/059	April 07, 2007
2007	2007	Landsat ETM	126/060	April 23, 2007
2007	2007	Landsat ETM	127/059	August 01, 2006
2007	2007	Landsat ETM	127/059	July 03, 2007
2007	2007	Landsat ETM	127/060	July 03, 2007
2007	2007	Landsat ETM	128/058	May 23, 2007
2005	2005	Landsat ETM-7	125/060	March 09, 2005
2005	2005	Landsat ETM-7	125/061	March 09, 2005
2005	2005	Landsat ETM-7	126/059	August 07, 2005
2005	2005	Landsat ETM-7	126/060	August 07, 2005
2005	2005	Landsat ETM-7	126/061	July 07, 2005
2005	2005	Landsat ETM-7	126/061	October 10, 2005
2005	2005	Landsat ETM-7	127/059	April 08, 2005
2005	2005	Landsat ETM-7	127/060	April 08, 2005
2005	2005	Landsat ETM-7	128/58	Jun 18, 2005
2005	2005	Landsat ETM-7	128/59	Aug 5, 2005
2004	2004	Landsat ETM-7	125/060	March 04, 2003
2004	2004	Landsat ETM-7	125/061	May 25, 2004
2004	2004	Landsat ETM-7	126/059	July 19, 2004
2004	2004	Landsat ETM-7	126/060	June 01, 2004
2004	2004	Landsat ETM-7	126/060	July 19, 2004
2004	2004	Landsat ETM-7	126/061	October 07, 2004
2004	2004	Landsat ETM-7	127/059	March 20, 2004
2004	2004	Landsat ETM-7	127/059	March 04, 2004
2004	2004	Landsat ETM-7	127/060	March 04, 2004
2004	2004	IRS-P6	127/060	June 23, 2004
2004	2004	Landsat ETM-7	128/58	May 14, 2004
2000	2000	Landsat ETM-7	125/060	September 1, 1999
2000	2000	Landsat ETM-7	125/060	April 15, 2001
2000	2000	Landsat ETM-7	125/061	December 3, 1998
2000	2000	Landsat ETM-7	125/061	September 1, 1999
2000	2000	Landsat ETM-7	126/059	May 21, 2000
2002	2000	Landsat ETM-7	126/059	December 18, 2001
2002	2000	Landsat ETM-7	126/059	July 14, 2002
2000	2000	Landsat ETM-7	126/060	May 21, 2000
2000	2000	Landsat ETM-7	126/060	March 05, 2001
2002	2000	Landsat ETM-7	126/060	Aug 15, 2002
2002		Landsat ETM-7	126/060	Apr 25, 2002
2000	2000	Landsat ETM-7	126/061	May 5, 2000
2000	2000	Landsat ETM-7	126/061	July 8, 2000
2002	2000	Landsat ETM-7	126/061	July 11, 2001
2002	2000	Landsat ETM-7	126/061	August 15, 2002

Forest Cover Analysis	Land Cover Analysis	Satellite	Path/Row	Date of Acquisition
2000	2000	Landsat ETM-7	127/059	April 26, 2000
2000	2000	Landsat ETM-7	127/059	May 31, 2001
2002		Landsat ETM-7	127/059	Jul 5, 2002
2000	2000	Landsat ETM-7	127/060	April 26, 2000
2000	2000	Landsat ETM-7	127/060	September 01, 2000
2000	2000	Landsat ETM-7	127/060	December 06, 2000
2002	2000	Landsat ETM-7	127/060	May 18, 2002
	2000	Landsat ETM- 7 (master sid)	Middle Sumatra	2000 data compiled
	1995	Landsat TM-5	125/060	May 11, 1996
	1995	Landsat TM-5	125/061	June 17, 1995
	1995	Landsat TM-5	126/059	June 19, 1995
	1995	Landsat TM-5	126/060	September 15, 1993
	1995	Landsat TM-5	126/060	1996
	1995	Landsat TM-5	126/061	April 11, 1996
	1995	Landsat TM-5	126/061	September 23, 1996
	1995	Landsat TM-5	127/060	May 09, 1995
	1990	Landsat TM-5	125/060	September 13, 1989
	1990	Landsat TM-5	125/061	June 09, 1989
	1990	Landsat TM-5	126/059	February 14, 1991
	1990	Landsat TM-5	126/060	June 03, 1990
	1990	Landsat TM-5	127/060	June 15, 1992
	1990	Landsat TM- 5 (master sid)	Middle Sumatra	1990 data compiled

Appendix 6.—*Land Use Zoning Classes used in May 2007 version of draft new land use plan for Riau produced by Transferra, Jakarta, Indonesia and our classification in likely land covers.*

Original Bahasa Indonesia	English Translation
"Infrastructure"	
Areal Pengembangan Perkotaan Utama (PKN,PKW,PKL) dan Pengembangan Perkotaan Baru	Existing (PKN,PKW,PKL) and New Urban Development Area
Pemukiman Perkotaan dan Perdesaan/Perkampungan Eksisting	Urban and Legal Rural Settlement
Kawasan Industri/Industry Estate (Luas Kawasan Definitif 20 – 400 ha)	Industrial Estate (Infrastructure of 20-400 ha)
"Oil Mining"	
Areal Pertambangan Minyak Bumi	Oil Mining
"Peat Mining"	
Areal Penambangan Gambut (di Kec. Perawang -Kab. Siak)	Peat Mining
"Natural Vegetation"	
Buffer Kawasan Lindung	Protected Area Buffer Zone
Hutan Adat	Customary-Law Community Forest
Jalur Hijau Penahanan Intrusi Air Laut (500 m Kiri-kanan Muara Sungai dan Sungai)	Green Belt to Block Sea Water Intrusion (500 m left and right of River Estuary and River)
Kawasan Cagar Alam (Buffer 500 – 1000 Meter)	Natural Reserve (Buffer 500 – 1000 Meter)
Kawasan Hutan Lindung (Kebijakan Khusus Pemerintah Daerah)	Protected Forest Area (managed under Provincial or District Government policy)
Kawasan Hutan Lindung (Kemiringan Lereng >40%)	Protected Forest Area (Slope >40%)
Kawasan Hutan Lindung (Kemiringan Lereng 20%-40%)	Protected Forest Area (Slope 20%-40%)
Kawasan Hutan Lindung Gambut	Protected Peat Swamp Forest
Kawasan Hutan Resapan Air	Water Catchment Forest
Kawasan Hutan Wisata	Ecotourism Forest
Kawasan Pantai Berhutan Bakau	Mangrove Forest
Kawasan Penelitian dan Pengembangan Gambut	Area for Research on Development of Peatland
Kawasan Pusat Latihan Gajah	Elephant Training Center
Kawasan Sempadan Pantai (Minimal 100 Meter dari Titik Pasang Tertinggi ke Arah Darat)	Coast Line Area (Minimum of 100 meter away from the Highest Tide to the Land

Kawasan Suaka Margasatwa (Buffer 500 – 1000 Meter)	Wildlife Reserve (Buffer 500 – 1000 meter)
Kawasan Taman Hutan Raya	City Park Area
Kawasan Taman Nasional (Buffer 500 – 1000 Meter)	National Park (Buffer 500 – 1000 Meter)
Kawasan Wisata	Ecotourism Area
Sempadan Sungai (Hanya Diplot Untuk Sungai-sungai Besar, 100m Kiri-Kanan Sungai)	River Bank Area (only along large rivers, 100 m Left-Right of River)
"Any Plantation"	
Kawasan Hutan Produksi Konversi (Pengembangan Perkebunan/Tanaman Tahunan)	Convertible Production Forest Area (Development of Plantation/multi year)
"Rubber or Acacia Plantation"	
Kawasan Agroforestry	Agroforestry Area
Kawasan Hutan Kemasyarakatan (di Atas Tanah Negara)	Community Forest Area (on national forest land)
"Acacia Plantation"	
Kawasan Hutan Produksi Diarahkan Sebagai HPHTI	Production Forest for HPHTI (HPH to be converted to industrial timber plantation)
Kawasan Hutan Produksi Tanaman Industri	Production Forest for Industrial Timber Plantation
"Oil Palm Plantation"	
Kawasan Perkebunan Besar Negara/Swasta (Termasuk di Dalamnya Koperasi)	Large State-Owned or Private Plantation Estate (including Cooperatives)
Kawasan Perkebunan Rakyat	Community Plantation /Smallholder
Kawasan Perkebunan Rakyat (Eksisting)	Community Plantation /Smallholder (Existing)
"Timber Plantation"	
Kawasan Hutan Rakyat (di Atas Tanah Rakyat)	Community Forest Area (on Community Land)
"Agriculture"	
Kawasan Hutan Produksi Konversi (Pengembangan Pertanian Lahan Basah)	Convertible Production Forest Area (Development of Wet Land Agriculture)
Kawasan Hutan Produksi Konversi (Pengembangn Pertanian Lahan Kering)	Convertible Production Forest Area (Development of Dry Land Agriculture)
Kawasan Pertanian Lahan Basah	Wet Land Agriculture
Kawasan Pertanian Lahan Basah (Eksisting)	Wet Land Agriculture (Existing)
Kawasan Pertanian Lahan Kering	Dry Land Agriculture
Kawasan Pertanian Lahan Kering (Eksisting)	Dry Land Agriculture (Existing)

Appendix 7.—*Assumptions for Biomass Estimates.*

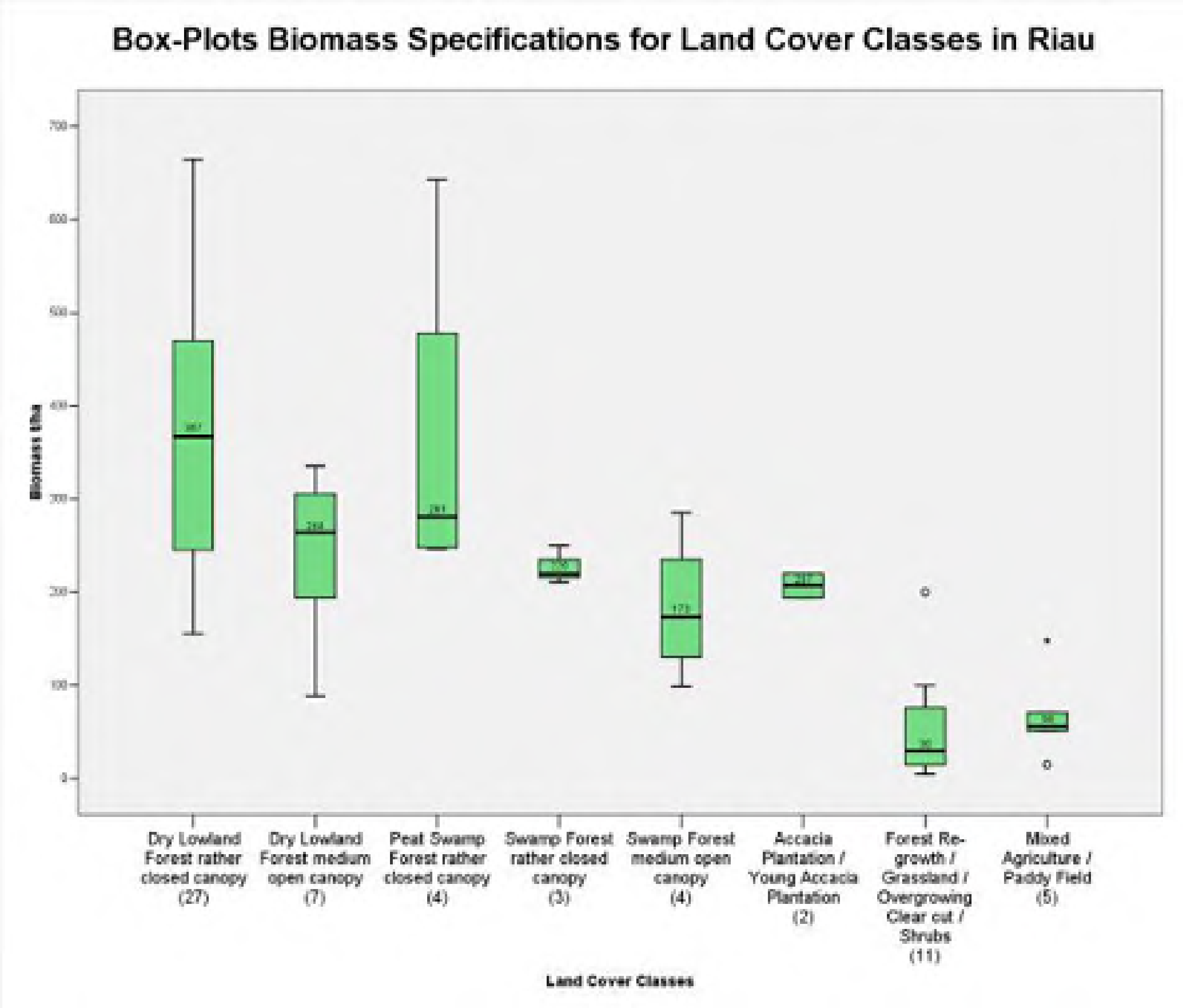


Figure 1.-- *Boxplots showing biomass specifications for selected classes*

ID	Type	Author	Measurement method	Country /region	land use	Measurement year	Drainage depth (cm) mean	peat thickness (cm)	Years after reclamation or burning	CO_2 emission from soil surface (including autotrophic root respiration) (tonnes CO_2/ha/year)
<Natural forest (including drained forest)>										
1	NF	Chimner 2004	GFM	Kosrae island, Micronesia	Pristine forested wetland	2001-2002	6	#NV	no	8
2	NF	Chimner & Ewel 2004	GFM	Kosrae island, Micronesia	Secondary forest	2001-2002	-1	#NV	no	8
3	NF	Furukawa et al. 2005	GFM	Jambi, Indonesia	Drained forest	2000-2002	18	#NV	20	86
4	NF	R. Hatano, unpublished data	GFM	Central Kalimantan, Indonesia	Peat swamp forest	2003-2004	32	200-300	no	36
5	NF	R. Hatano, unpublished data	GFM	Central Kalimantan, Indonesia	Peat swamp forest	2004-2005	14	200-300	no	35
6	NF	Hadi et al. 2005	GFM	South Kalimantan, Indonesia	Secondary forest	2000-2001	38	>200	<10?	127
7	NF	Jauhiainen et al. 2005	GFM	Central Kalimantan, Indonesia	Peat swamp forest	1999-2001	17	200-300	no	35
8	NF	R. Hatano, unpublished data	GFM	Central Kalimantan, Indonesia	Peat swamp forest	2003-2004	33	200-300	no	37
9	NF	R. Hatano, unpublished data	GFM	Central Kalimantan, Indonesia	Peat swamp forest	2004-2005	14	200-300	no	36
10	NF	Jauhiainen et al. 2004	GFM	Central Kalimantan, Indonesia	Selectively logged forest (near tree)	2001-2002	21	350-485	no	76
11	NF	Darung et al. 2005	GFM	Central Kalimantan, Indonesia	Slightly drained forest	2002-2003	55	350-485	no	51
12	NF	Darung et al. 2005	GFM	Central Kalimantan, Indonesia	Slightly drained forest	2003-2004	32	350-485	no	62
13	NF	Melling et al. 2005	GFM	Sarawak, Malaysia	Mixed peat swamp forest	2002-2003	45	480	no	77
14	NF	Inubushi et al. 2003, 2005	GFM	South Kalimantan, Indonesia	Secondary forest	1999-2001	18	100-200	no	44
<Cleared or Burnt forest (no tree)>										
15	CB	Darung et al. 2005	GFM	Central Kalimantan, Indonesia	Burnt forest	2002-2003	56	325-520	<1	22
16	CB	Darung et al. 2005	GFM	Central Kalimantan, Indonesia	Burnt forest	2003-2004	28	325-520	1	24
17	CB	Jauhiainen et al. 2004	GFM	Central Kalimantan, Indonesia	Cleared burned area (high surface)	2001-2002	19	325-520	4-5	23
18	CB	Jauhiainen et al. 2004	GFM	Central Kalimantan, Indonesia	Cleared burned area (depression)	2001-2002	-1	325-520	4-5	28
19	CB	Jauhiainen et al. 2004	GFM	Central Kalimantan, Indonesia	Clear felled but recovering forest	2001-2002	21	325-520	4-5	34
20	CB	Darung et al. 2005	GFM	Central Kalimantan, Indonesia	Burnt forest	2002-2003	27	325-520	<1	48
21	CB	Darung et al. 2005	GFM	Central Kalimantan, Indonesia	Burnt forest	2003-2004	-1	325-520	1	26
<Agricultural field and plantation>										
22	AG	Chimner & Ewel 2004	GFM	Kosrae island, Micronesia	Taro patch (cultivated)	2001-2002	1	#NV	>50?	5
23	AG	Furukawa et al. 2005	GFM	Jambi, Indonesia	Cassava field	2000-2002	24	#NV	<1	64
24	AG	Furukawa et al. 2005	GFM	Jambi, Indonesia	Upland paddy field	2000-2002	13	#NV	5	73
25	AG	Furukawa et al. 2005	GFM	Jambi, Indonesia	Lowland paddy field	2000-2002	-5	#NV	5	10
26	AG	Darung et al. 2005	GFM	Central Kalimantan, Indonesia	Cropland	2002-2003	74	250	>20	84
27	AG	Darung et al. 2005	GFM	Central Kalimantan, Indonesia	Cropland	2003-2004	53	250	>20	92
28	AG	R. Hatano, unpublished data	GFM	Central Kalimantan, Indonesia	Cropland	2004-2005	50	250	>20	124
29	AG	R. Hatano, unpublished data	GFM	Central Kalimantan, Indonesia	Cropland	2005-2006	63	250	>20	106
30	AG	R. Hatano, unpublished data	GFM	Central Kalimantan, Indonesia	Cropland	2006-2007	90	250	>20	150
31	AG	Darung et al. 2005	GFM	Central Kalimantan, Indonesia	Glassland	2002-2003	70	270-280	>20	68
32	AG	Darung et al. 2005	GFM	Central Kalimantan, Indonesia	Glassland	2003-2004	65	270-280	>20	77
33	AG	R. Hatano, unpublished data	GFM	Central Kalimantan, Indonesia	Glassland	2004-2005	95	270-280	>20	98
34	AG	R. Hatano, unpublished data	GFM	Central Kalimantan, Indonesia	Glassland	2005-2006	84	270-280	>20	128
35	AG	R. Hatano, unpublished data	GFM	Central Kalimantan, Indonesia	Glassland	2006-2007	104	270-280	>20	118
36	AG	Darung et al. 2005	GFM	Central Kalimantan, Indonesia	Cropland	2002-2003	75	280	>20	78
37	AG	Darung et al. 2005	GFM	Central Kalimantan, Indonesia	Cropland	2003-2004	73	280	>20	100
38	AG	R. Hatano, unpublished data	GFM	Central Kalimantan, Indonesia	Cropland	2004-2005	74	280	>20	106
39	AG	R. Hatano, unpublished data	GFM	Central Kalimantan, Indonesia	Cropland	2005-2006	83	280	>20	165
40	AG	R. Hatano, unpublished data	GFM	Central Kalimantan, Indonesia	Cropland	2006-2007	92	280	>20	107
41	AG	Darung et al. 2005	GFM	Central Kalimantan, Indonesia	Cropland	2002-2003	64	240	>20	80
42	AG	Darung et al. 2005	GFM	Central Kalimantan, Indonesia	Cropland	2003-2004	45	240	>20	109
43	AG	R. Hatano, unpublished data	GFM	Central Kalimantan, Indonesia	Cropland	2004-2005	55	240	>20	114
44	AG	R. Hatano, unpublished data	GFM	Central Kalimantan, Indonesia	Cropland	2005-2006	67	240	>20	135
45	AG	R. Hatano, unpublished data	GFM	Central Kalimantan, Indonesia	Cropland	2006-2007	85	240	>20	131
46	AG	Jauhiainen et al. 2004	GFM	Central Kalimantan, Indonesia	farm field	2001-2002	29	200-300	>10	19
47	AG	Inubushi et al. 2003, 2005	GFM	South Kalimantan, Indonesia	Abandoned upland crops field	1999-2001	0	70-100	>20?	36
48	AG	Inubushi et al. 2003, 2005	GFM	South Kalimantan, Indonesia	Abandoned paddy fields	1999-2001	20	10-40	>20?	56
49	AG	Hadi et al. 2005	GFM	South Kalimantan, Indonesia	Paddy field	2000-2001	0	100-200	<10?	51
50	AG	Hadi et al. 2005	GFM	South Kalimantan, Indonesia	Rice-soybean rotation field	2000-2001	18	20-40	<10?	74
51	PL	Melling et al. 2005	GFM	Sarawak, Malaysia	Sago plantation	2002-2003	27	650	5	40
52	PL	Melling et al. 2005	GFM	Sarawak, Malaysia	Oil palm plantation	2002-2003	60	555	5	55

Figure 2.-- *Literature specifications for peat decomposition.*

WWF land cover classes	Class description	Region	Literature Source	Biomass Specifications [t/ha]	Biomass used for Calculations [t/ha]
Dry Lowland Forest rather closed canopy	mixed dipterocarps-dense stocking, flat to undulating	Sarawak	Brown (1997)	355,0	**367**
	mixed dipterocarps-medium stocking, flat to mountainous	Sarawak	Brown (1997)	305,0	
	old-growth dipterocarp	Philippines	Brown (1997)	445,0	
	closed-broadleaf tropical forest	Indonesia	Lasco (2002)	508,0	
	natural forest	Indonesia	Hairiah et al. (2001)	508,0	
	medium humus podzol	Sarawak	Bruenig (1977)	452,0	
	shallow humus podzol	Sarawak	Bruenig (1977)	350,0	
	evergreen needleleaf forest	Asia	Michel et al. (2005)	367,0	
	evergreen broadleaf forest	Asia	Michel et al. (2005)	233,5	
	deciduous needleleaf forest	Asia	Michel et al. (2005)	189,0	
	deciduous broadleaf forest	Asia	Michel et al. (2005)	200,0	
	mixed forest	Asia	Michel et al. (2005)	222,5	
	tropical forest	Malaysia	Brown and Gaston (1996)	230,0	
	primary forest	Central Kalimantan, Barito Ulu	Brearly et al. (2004)	358,0	
	primary forest	East Kalimantan	Prakoso (2006)	155,5	
	lowland forest	Indonesia	Garzuglia et al (2003)	240,0	
	lowland evergreen rainforest	Malaysia, Pasoh	MacKinnon et al. (1996)	664,0	
	lowland evergreen rainforest	Malaysia, Pasoh	MacKinnon et al. (1996)	475,0	
	lowland evergreen rainforest broad ridge crest	Sarawak, Mula	MacKinnon et al. (1996)	650,0	
	lowland evergreen rainforest valley alluvium	Sarawak, Mula	MacKinnon et al. (1996)	250,0	
	lowland evergreen rainforest over limestone	Sarawak, Mula	MacKinnon et al. (1996)	380,0	
	lowland evergreen rainforest heath forest	Sarawak, Mula	MacKinnon et al. (1996)	470,0	
	kerangas	Borneo	MacKinnon et al. (1996)	470,0	
	mixed dipterocarp	Borneo	MacKinnon et al. (1996)	650,0	
	limestone	Borneo	MacKinnon et al. (1996)	380,0	
	Asia tropical forest undisturbed	Asia	Brown et al. (1993)	438,0	
	tropical rain forest Asia insular	Asia	IPCC (2006)	350,0	
Dry Lowland Forest medium open canopy	forest fallow	Malaysia, Peninsular	Brown (1997)	140,0	**264**
	logged dipterocarp	Philippines	Brown (1997)	335,0	
	commercial logging	Indonesia	Hairiah et al. (2001)	300,0	
	logged forest	Sumatra, Pasir Mayang	Prasetyo et al. (2000)	310,4	
	old secondary forest	Central Kalimantan, Barito Ulu	Brearly et al. (2004)	264,0	
	secondary forest	East Kalimantan	Prakoso (2006)	89,0	
	Asia tropical forest disturbed	Asia	Brown et al. (1993)	248,0	
Dry Lowland Forest very open canopy	burnt primary forest	East Kalimantan	Prakoso (2006)	73,0	**73**
Peat Swamp Forest rather closed canopy	mixed swamp forest	central Kalimantan	Waldes and Page (2001)	312	**281**
	low pole forest	central Kalimantan	Waldes and Page (2001)	249	
	tall interior forest	central Kalimantan	Waldes and Page (2001)	643	
	shallow peat bog	Sarawak	Bruenig (1977)	246	
Peat Swamp Forest medium open canopy	-	-	-	-	**234**
Peat Swamp Forest very open canopy	-	-	-	-	**62**
Swamp Forest rather closed canopy	freshwater swamp	Malaysia, Peninsular	Brown (1997)	220,0	**220**
	swamp forest	Indonesia	Garzuglia et al (2003)	211,0	
	alluvial	Borneo	MacKinnon et al. (1996)	250,0	
Swamp Forest medium open canopy	disturbed freshwater swamp	Malaysia, Peninsular	Brown (1997)	285,0	**173**
	logged freshwater swamp	Malaysia, Peninsular	Brown (1997)	185,0	
	logged freshwater swamp forest	Malaysia	Brown et al. (1989)	161,7	
	disturbed freshwater swamp forest	Malaysia	Brown et al. (1989)	99,2	
Swamp Forest very open canopy	-	-	-	-	**44**
Mangrove Forest rather closed canopy	mangrove forest	Indonesia	Garzuglia et al (2003)	187	**187**
Mangrove Forest medium open canopy	-	-	-	-	**140**
Mangrove Forest very open canopy / Young Mangrove	-	-	-	-	**37**
Accacia Plantation / Young Accacia Plantation	broadleaf plantation	Asia	IPCC (2006)	220	**207**
	Acacia decurrens Willd (12 years)	Indonesia	Suharlan et al. (1993)	194	**104**
Coconut Plantation	coconut plantation	Malaysia	Henson (2005)	80	**80**
Rubber Plantation	broadleaf plantation	Asia	IPCC (2006)	220	**220**
Small Holder Rubber					
Paraserianthes	Paraserianthes falcataria (12 years)	Indonesia	Suharlan et al. (1993)	242	**242**
Oil Palm Plantation / Young Oil Palm Plantation	oil palm plantation	South East Asia	IPCC (2006)	136	**109**
Small Holder Oil Palm / Small Holder Young Oil Palm Plantation					
Forest Re-growth (Belukar) / Forest Re-growth on Swampy / Grassland / Hutan Kota / Mixed Garden / Overgrowing Clear cut-Shrubs / Shrubs (Semak/Belukar Muda) / Shrubs on Swampy	Imperate cylindrica	Indonesia	de Groot et al. (2005)	5	**30**
	Grassland	Sumatra, Pasir Mayang	Prasetyo et al. (2000)	12	
	Grassland	tropics	Murdiyasso and Wasrin (1995)	30	
	Grassland	Asia	Michel et al. (2005)	13	
	Woodland	Asia	Michel et al. (2005)	100	
	Wooded grassland	Asia	Michel et al. (2005)	33	
	Closed shrubland	Asia	Michel et al. (2005)	72	
	Open shrubland	Asia	Michel et al. (2005)	16	
	Savannah	tropics	Murdiyasso and Wasrin (1995)	80	
	Savannah	tropics	Murdiyasso and Wasrin (1995)	200	
	Bush/shrub	Sumatra, Pasir Mayang	Prasetyo et al. (2000)	30	
Swamp Grasses / Fernland	-	-	-	-	**44**
Mixed Agriculture / Paddy Field	Cropland	Asia	Michel et al. (2005)	51,0	**56**
	Cultivated lands and secondary vegetation in,	Sumatra, Pasir Mayang	Prasetyo et al. (2000)	71,0	
	Upland rice/bush falllow rotation	Indonesia	Hairiah et al. (2001)	148,0	
	Cash crops plantation	Sumatra, Pasir Mayang	Prasetyo et al. (2000)	56,0	
	Paddy field	Sumatra, Pasir Mayang	Prasetyo et al. (2000)	15,0	
Water Body	-	-	-	-	**-**
Cleared / Cleared post Accacia harvested / Cleared, for Oil Palm Plantation / Airport / Sand Mining / Sediment / Settlement / Town / Factory	-	-	-	-	**-**

Figure 3.—*Allocation of literature specifications to Riau land cover classes. For plantations (red) a lower value was assumed to account for the different stages of the life cycle.*

Appendix 8.—*Literature for biomass estimation*

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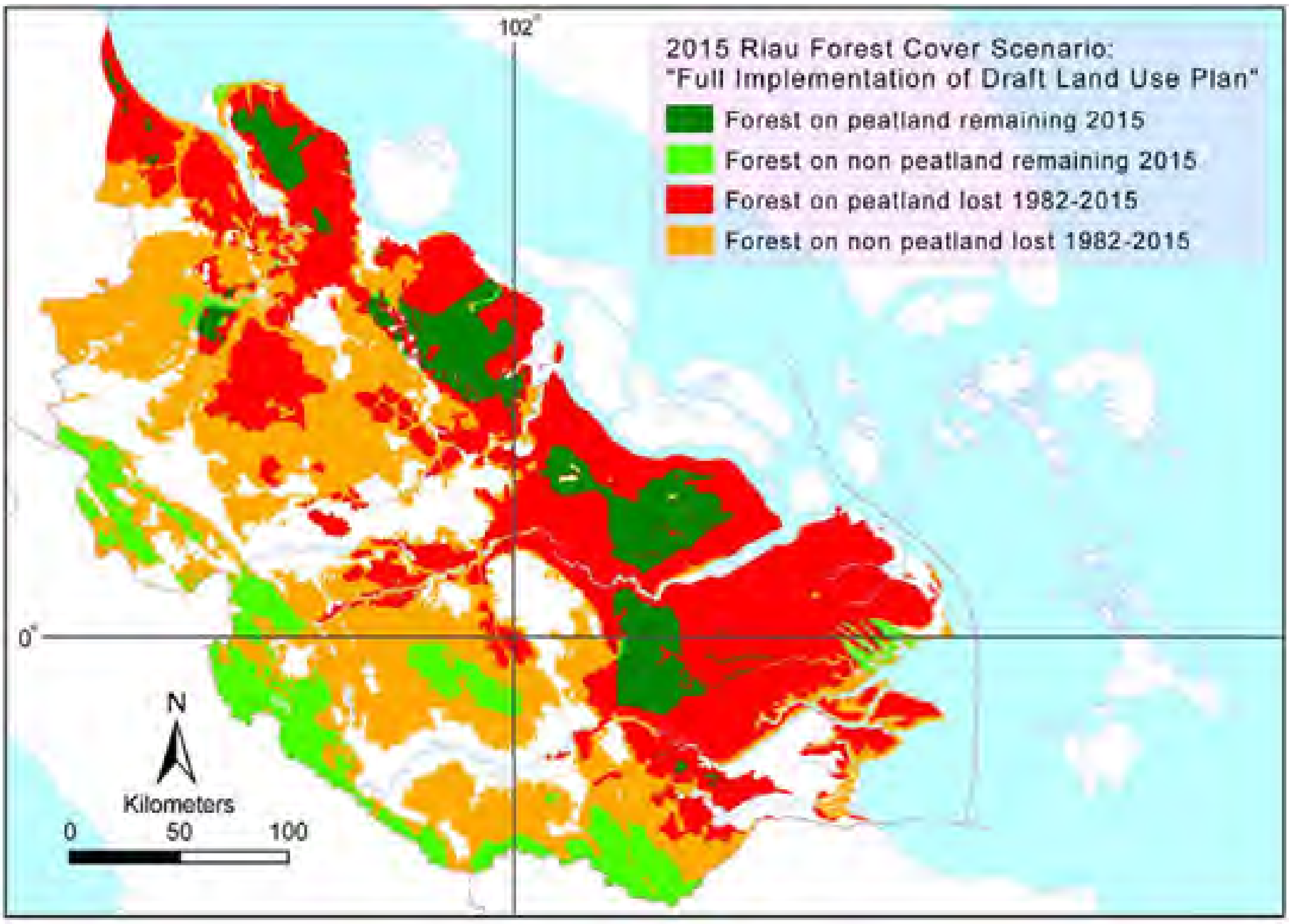
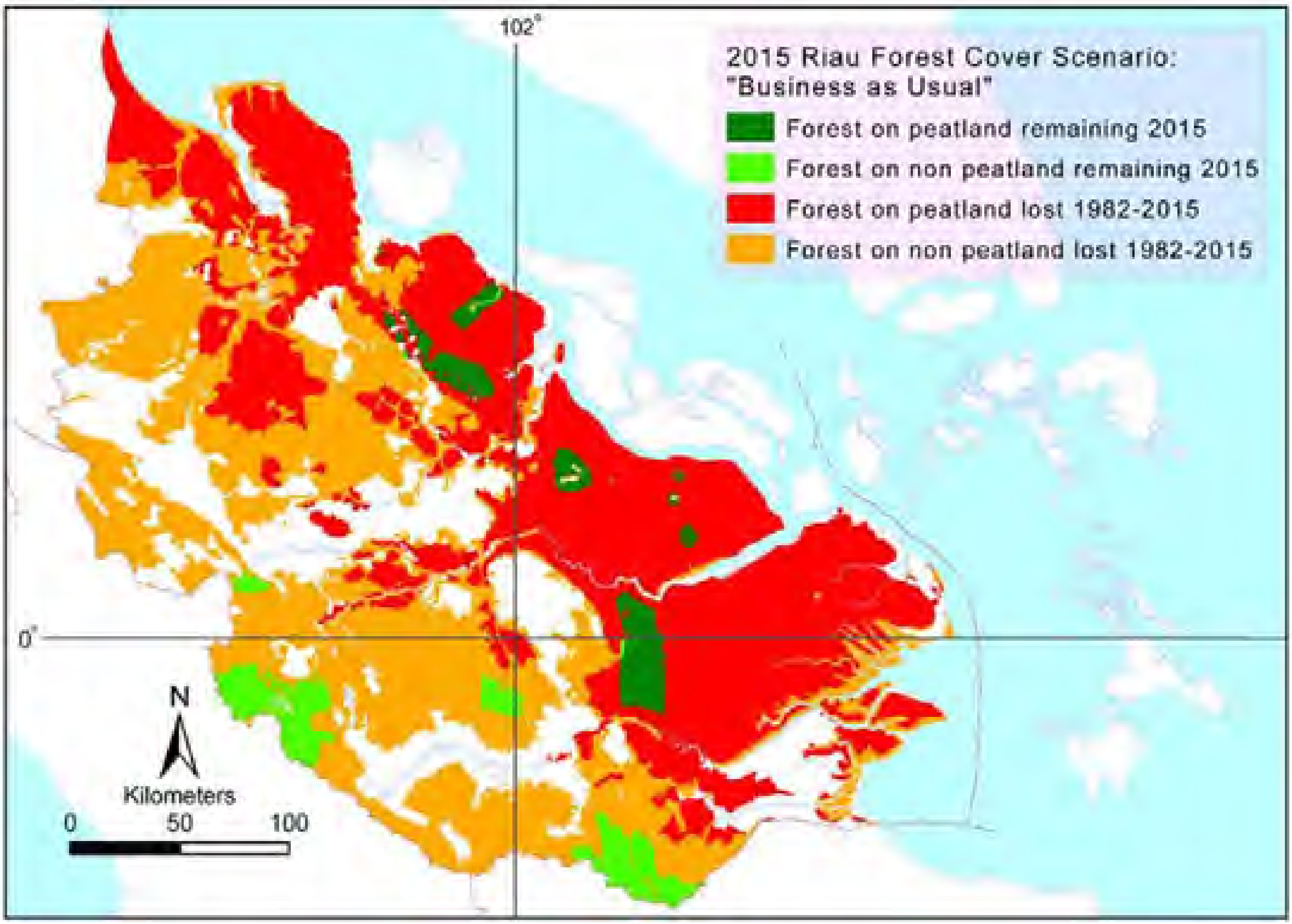


102°
2015 Riau Forest Cover Scenario:
"Full Implementation of Draft Land Use Plan"
Forest on peatland remaining 2015
Forest on non peatland remaining 2015
Forest on peatland lost 1982-2015
Forest on non peatland lost 1982-2015
0°
N
Kilometers
0 50 100



102°
2015 Riau Forest Cover Scenario:
"Business as Usual"
Forest on peatland remaining 2015
Forest on non peatland remaining 2015
Forest on peatland lost 1982-2015
Forest on non peatland lost 1982-2015
0°
N
Kilometers
0 50 100

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