DRIVERS OF LAND USE CHANGE AND THE ROLE OF PALM OIL PRODUCTION IN INDONESIA AND MALAYSIA

OVERVIEW OF PAST DEVELOPMENTS AND FUTURE PROJECTIONS

Final Report

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EXECUTIVE SUMMARY

This study provides insight into **land use changes (LUC) in Indonesia and Malaysia** and into the specific role that palm oil production and its expansion have played in the past and may play in the future in both countries. In relation to future land use changes induced by palm oil production expansion also the GHG emissions of this LUC are analysed to indicate the sustainability (from a GHG emission perspective) of the various palm oil expansion projections.

Past LUC

While large scale LUC has occurred both in Indonesia and Malaysia over the past 30 years (Figure I), the countries differ in the actual changes that took place. In **Indonesia the largest change has occurred in forest covered land** (a decrease from 130 Mha in 1975 to 86 million in 2003), while agricultural land has increased (from 38 Mha in 1975 to 48 million in 2005) – including an increase of land utilised by palm oil production (from 0.2 Mha in 1975 to 5.5 Mha in 2005 and even further to 6.1 Mha in 2006). In **Malaysia** deforestation was very strong until the beginning of the 1990's, slowed down considerably since then but still happens today. **The largest change in land use was seen in land cultivated for palm oil, which increased from 0.6 Mha in 1975 to 2 Mha in 1990 and 4 Mha in 2005**, while other permanent crops, primarily natural rubber and coconut plantations decreased strongly since the beginning of the 1990's (at a large part being replaced by palm oil).

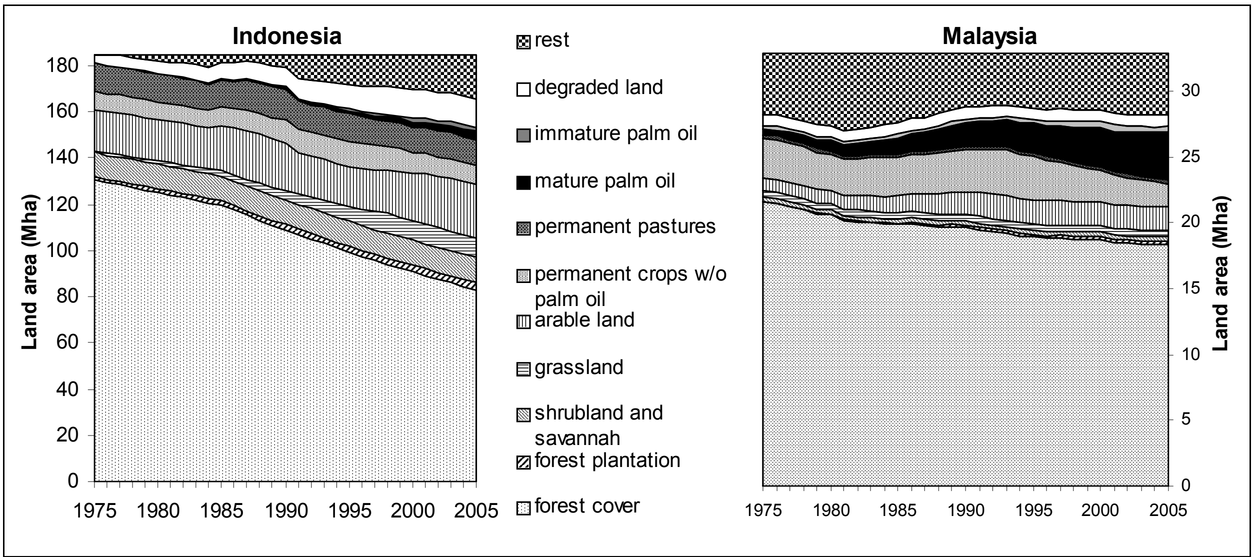

Figure I: Overview of past LUC in Indonesia (left) and in Malaysia (right): 1975 to 2005

Causes and Drivers of LUC

For **Indonesia**, it was found that there are **many, interrelated causes and underlying drivers** that are responsible for this LUC. It is shown that palm oil alone cannot explain the large loss in forest cover but that rather a web of interrelated direct causes (including palm oil production expansion) and underlying drivers are responsible. Important direct causes were found to be logging, palm oil expansion and other agricultural production and forest fires, while underlying drivers were found to be population growth, agriculture and forestry prices, economic growth and policy and institutional factors. In **Malaysia** the most important **causes of LUC vary per region**: In Sabah and Sarawak the most important causes have been **timber extraction and shifting cultivation** while in Peninsular Malaysia, and in recent years increasingly in Sabah, forest cover has been affected most by **conversion to agriculture**, mainly palm oil production. But also underlying drivers such as agricultural and forestry prices, economic growth and policy and institutional factors played a role in LUC in Malaysia.

Projected Future LUC Induced By Palm Oil Production Expansion

For each country four projections of future palm oil production were made based on information from different sources and stakeholders of palm oil production. Projections for **Indonesia** show that additional land requirements for future palm oil production expansion range between 5 and 20 Mha for the base case (assuming past yield trends), while the improved case (assuming increased yield trends and a 20% share of immature palms) shows a significant reduction in additional land requirements (now ranging from 1 to 7 Mha). For **Malaysia**, additional land requirements range between 1 and 4.5 Mha for the base case and between no additional land required to an additional 3 Mha for the improved case. This indicates that also in Malaysia a significant reduction in land requirements (even if at a smaller rate than in Indonesia) can be achieved when higher yields are obtained. The main reason for this smaller reduction can be found in that Malaysia currently has a low share of immature palms and that, in order to keep improving yields, it is necessary to increase this share (i.e. increased and/or earlier replanting). As a result, the area of immature oil palms in the improved case increases compared to the base case. In contrast, Indonesia has currently a large share of immature palms but is assumed to decrease in the future.

The palm oil expansion projections are matched with projections on reference land use to determine whether enough land is available for these palm oil expansion projections to be feasible. The projections of reference land use are primarily based on whether deforestation is allowed to occur, on whether this deforested land may be used for palm oil production or other expansion of agriculture, on whether peatland may be used for palm oil production, and on the availability and use of degraded land. The matching of land requirements and land availability shows for Indonesia that very large expansion of palm oil production is possible at the expense of forest cover. But additional forested land and peatland are not necessarily required for most projections of palm oil production expansion to be feasible. This is because yield improvements can largely reduce land requirements while also large amounts of degraded land exist in Indonesia. However, the current use and ownership of degraded land need to be accounted for before expansion on degraded land so that it does not cause indirect LUC, social conflicts and human rights violations. In addition, uncertainties about the actual extent and location of degraded land in Indonesia are high and need to be further investigated. While much less degraded land is available for sustainable palm oil production expansion in Malaysia, also these issues must be accounted for there. In general, the land area available for palm oil production expansion but particularly sustainable expansion potential is more limited in Malaysia, which is due the smaller total land area but also because of the better land management than in Indonesia. As in Indonesia, yield improvements are also an important component of allowing potentially sustainable expansion in Malaysia. Yield improvements in the short term in both countries are mainly possible by applying fertiliser and other inputs more appropriately, practising good harvesting standards and quickly transporting the fruit to the mill. In the long term also proper replanting (with respect to the timing of replanting and replanting with high yielding palms) will be important.

GHG Emissions Associated With LUC Induced By Palm Oil Production

Large ranges of GHG emissions are associated with future LUC induced by palm oil production in either country, ranging from -40 million to +589 million tonne of CO_2 equivalent per year in **Indonesia** and from -6 million to 24 million tonne of CO_2 equivalent per year in **Malaysia**. The much smaller emissions of Malaysia are caused by the much smaller amounts of land that are projected to be converted to palm oil in Malaysia than in Indonesia. The **large ranges** in projected emissions are caused by the expansion on different land types: when palm oil is produced on former forest covered land or drained peatland large emissions (higher end of ranges) occur, while production on former degraded land shows that overall negative emissions are possible so that palm oil production would become a carbon sink.

Recommendations

Based on the analysis of this study the following recommendations are made to stimulate sustainable LUC (here primarily focussing on the changes induced by palm oil production expansion) in the future. Recommendations are made for palm oil producers, research groups, the Indonesian government, the Malaysian government and the international community around sustainable palm oil production.

Recommendations to palm oil producers
- *Improve yields*
- *Replant properly*
- *Improve oil extraction rate*
- *Reduce GHG emissions by better management of plantation*
- *Investigate potential environmental and social impacts of using degraded land*
- *No new plantings on peatland*

Recommendations to research groups
- *Create more knowledge on degraded land*
- *Create more knowledge on the use of degraded land for palm oil production*
- *Investigate the causes and chronological order of causes*
- *Determine forest cover in Malaysia*

Recommendations to Indonesian government
- *Reassess forest land classification*
- *Prevent production forest becoming unproductive*
- *Demarcate concessions for timber and palm oil plantations on degraded land*
- *Increase dissemination of best management practices of palm oil production*
- *Implement additional measures to stop deforestation*

Recommendations to Malaysian government
- *Reassess forest demarcation based on research findings of actual forest cover in Malaysia*
- *Demarcate concessions for timber and palm oil plantations on degraded land*
- *Disseminate information on best management practices of palm oil production*

Recommendations to international community
- *Extend sustainability certifications to include better management, improving yields and use of degraded land*
- *Stimulate improved management and yields*
- *Set up case studies on degraded land*
- *Implement measures to stop deforestation*

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ABBREVIATIONS

BPS	Indonesian Bureau of Statistics
CH_4	Methane
CO_2	Carbon dioxide
CPO	Crude palm oil
FFB	Fresh fruit bunches
FRA	FAO Forest Resources Assessment Report
FWI/GFW	Forest Watch Indonesia/Global Forest Watch
GDP	Gross domestic product
GHG	Greenhouse gas emissions
GLASOD	Global Assessment of Human Induced Soil Degradation
GLCCD	Global Land Cover Characteristics Database
IPOC	Indonesian Palm Oil Commission
LUC	Land use change
MOF	Indonesian Ministry of Forestry
Mha	Million hectares
MPOB	Malaysian Palm Oil Board
MTC	Malaysian Timber Council
NCR	Native customary rights (Malaysia)
N_2O	Nitrous oxide
OER	Oil extraction rate
PFAD	Palm fatty acid distillate
PFE	Permanent forest estate
POME	Palm oil mill effluent

1 INTRODUCTION

The production and use of palm oil for energy purposes (both for power generation and conversion to biodiesel) has resulted in a fierce public debate in which the sustainability of palm oil production is scrutinised. The production of palm oil in the most important producer countries, Indonesia and Malaysia, has come hand in hand with many environmental, ecological and social issues (see for example Casson, 2000, Wakker, 2004, Forest Watch Indonesia and Global Forest Watch, 2002, Colchester et al., 2006, Reijnders and Huijbregts, 2008). Palm oil production of the largest producer, Indonesia, takes place in areas where large scale deforestation and losses in biodiversity are observed, where CO_2 emission through losses of organic soil matter and original vegetation are high, and where forest and peatland fires are common. Moreover, there are also social problems associated with the rapid expansion of palm oil in Indonesia; these include mainly land tenure conflicts, labour rights issues (Wakker, 2004) but also rising prices of cooking oil based on palm oil (Casson, 2000).

In contrast, palm oil plantations are at present the most productive cropping system for producing vegetable oils with an average yield of 3.3 tonne palm oil per hectare and year (compared to 0.5 t ha^{-1} y^{-1} of soybean oil, 0.7 t ha^{-1} y^{-1} of sunflower oil and 1.3 t ha^{-1} y^{-1} of rapeseed oil) (Basiron and Weng, 2004). Moreover, palm oil's input-output energy ratio of 9.5 is much higher than of other crops (3 for rapeseed oil and 2.5 for soybean oil) (Malaysian Palm Oil Promotion Council, undated citing Wood and Corley, 1991). The direct ecological impacts of the plantations as such can, provided correct management, score relatively well compared to other crops used for production of biofuels, such as rapeseed or maize. Also, palm oil is generally a considerably cheaper feedstock than vegetal oils from temperate climates. Another potential benefit is also that palm oil plantations can be established on degraded or marginal lands, which have a much more limited role in food supplies and often represent limited biodiversity values. Establishment of palm oil plantations on such land can lead to net carbon sequestration in the soil and aboveground biomass over time. Thus, if it could be secured that palm oil plantations are only established on such lands, a fairly different 'sustainability score,' especially with respect to the greenhouse gas (GHG) balance, is very likely. Besides improving the GHG balance of palm oil, applying degraded land for oil palm expansion could also help reduce the pressure on forests, other nature reserves and agricultural land.

Because of the current discussions on the sustainability of palm oil and the expected growth in production and consumption, also for energy, further analysis is required to understand the impacts of palm oil production at large, as well as the improvement options of the production chain. Of all the impacts, this study focuses on the land use change (LUC) topic only. *It is the main objective of this study to provide insight into the developments in land use in Indonesia and Malaysia and the specific role of palm oil plantations in LUC until now so that possible boundary conditions (undesirable areas and possible areas) can be set for oil palm expansion in the future. As a second objective, this study compiles different projections for oil palm expansion in the future to consider possible future developments in land use in Indonesia and Malaysia and to determine under which conditions land may be available for palm oil production without conflicting with food supplies and protection of forests and other nature areas. In relation to LUC induced by palm oil production expansion also the GHG emissions of this LUC will be analysed to indicate the sustainability of the various projections.*

The following section describes the applied methodology (Chapter 2). The thereafter following sections present the results for Indonesia: An overview of LUC between 1975 and 2005 in Indonesia is presented first (Chapter 3). Then the direct causes of LUC and its underlying drivers in Indonesia are described (Chapter 4). Next, the projections of palm oil expansion in the future and of the future reference land use systems are described and the results for Indonesian LUC under different projections presented (Chapter 5). After that, GHG emissions of palm oil production are described and the overall GHG emissions are determined for the various projections of the previous chapter (Chapter 6).

The thereafter following sections focus on Malaysia: First an overview of LUC in Malaysia is presented (Chapter 7). Then the direct causes and underlying drivers of LUC in Malaysia are described (Chapter 8) and the results of the projections for palm oil production expansion and reference land use and their matching are presented (Chapter 9). Next, the GHG emissions from LUC induced by palm oil production expansion are portrayed (Chapter 10).

After presenting the analysis and its results for Indonesia and Malaysia, a discussion and a comparison of the results from both countries' analyses, of data availability and of the likeliness of reaching the projected yields follow (Chapter 11). In the final chapter, conclusions are drawn and recommendations for the Indonesian and Malaysian government, palm oil producers, research groups and the international community surrounding the sustainability of palm oil production are made (Chapter 12).

2 APPROACH

2.1 Past Land Use Change

An overview of past LUC is made by collecting data of the various individual land use categories from publicly available government statistics, government and NGO reports, academic literature and other sources available on the internet. Satellite images are not analysed in this study because of the large time and data requirements for such an analysis of both Indonesia and Malaysia. However, results of remote sensing studies are included whenever possible and available, and are compared to the compiled statistics.

The following land use categories are included in this study as they are the main land use categories and represent large fractions of the total land area:

- Forest[1]
- Agriculture[2]
- Palm oil
- Peatland
- Shrubland, savannah and grassland
- Degraded land
- Burnt and barren land[3]

Another land use category is *Urban and built-up* land, which makes up only a very small fraction of the total land area (less than 1% in Indonesia and Malaysia, Earthtrends, 2007c citing GLCCD) and is therefore not treated as an individual category in the rest of the analysis. Definitions of the various land use categories are provided in Appendix A. All remaining land not covered by the above-mentioned categories, including urban and built-up land, is combined in the category "*Rest*".

In order to make a time line of LUC, various assumptions and choices regarding the data on each land use category are necessary. The most important one to mention here is that presenting the change over the past 30 years in certain categories may be based on data points for only two years. In those cases, extrapolations were made for other years. This was done in order to provide a complete picture for all categories for the whole time period. All the details of the assumptions are presented together with the LUC overview in section 3.8 for Indonesia and section 7.8 for Malaysia.

2.2 Causes and Drivers of Land Use Change

In order to get a better understanding of the factors that influence LUC in Indonesia and Malaysia, the causes and drivers of LUC are studied. Direct causes of LUC are activities and actions that directly change land use (Geist and Lambin, 2002). Generally, there are multiple direct causes of LUC. Underlying drivers are "fundamental social processes" that underpin the direct causes (Geist and Lambin, 2002). As with the direct causes of LUC, also the underlying drivers are multiple. An underlying factor can drive various direct causes and various underlying factors together can also drive only one direct cause.

Based on literature information and statistics, the main direct causes and underlying drivers of LUC are qualitatively described, supporting data is shown and the causes and drivers' shares in LUC are presented whenever this information is available from literature.

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[1] Forest is divided into forest land and forest cover in this study because large discrepancies were found in governmentally assigned forest land and actual forest cover of these lands (see section 3.1).
[2] Agriculture is divided into arable land (temporary crops), permanent crops and permanent pastures.
[3] Burnt and barren land is not presented individually in the overview of land use change in Indonesia and Malaysia because the available information was found to be too limited. See section 3.7 and 7.7.

2.3 Projected Palm Oil Production Expansion

Future palm oil production is projected on the basis of different datasets. For Indonesia and Malaysia two projections are based on: 1) extrapolation of past trends of land cultivated with oil palm and 2) FAO projections of palm oil production. For Indonesia two more projections are made based on 3) projections of the Indonesian Palm Oil Commission (IPOC) for land expansion and 4) expansion estimates found by Colchester et al. in their study "Promised Land" (Colchester et al., 2006). For Malaysia, the two additional projections are based on 3) the projections of the Malaysian Palm Oil Board (MPOB as presented by Jalani et al., 2002) for land expansion and 4) expansion estimates made by the 9th Malaysian Plan (Economic Planning Unit, 2006). Some of these projections are based on land expansion of the palm oil industry and others are based on annual growth in palm oil production. For the ladder, palm oil production is translated into the land area required to make this production possible. Two cases are studied, which are *base case* and *improved case*. The base case refers to yield developments and a share of immature palms as in the past, which amounts to a yield of 3.5 tonne CPO per hectare per year for Indonesia and 4.3 tonne CPO per hectare per year for Malaysia and a share of immature palms of 29% for Indonesia and 10% for Malaysia. The improved case assumes that yields can be improved by 3% each year as suggested by Dros (2003) so that yields amount to 5.85 tonne CPO per hectare per year in Indonesia and 6.1 tonne CPO per hectare per year in Malaysia in 2020 while the share of immature palms is assumed to amount to 20% as suggested to be appropriate by Jalani et al. (2002). Both of the cases and the various projections are explained in more detail for each country in the appropriate sections below (section 5.1 for Indonesia and section 9.1 for Malaysia).

2.4 Reference land use

The term "reference land use" refers to the changes in all land use categories except palm oil and thereby determines how much land in each land category may become available for conversion to palm oil production in the future. It includes the following categories: forest (cover), agriculture, degraded land, timber plantations. Besides determining available land, the reference land use systems also refer to the type of land that may be converted to oil palm cultivation (Table 1). Three projections for reference land use are developed, which are based on different changes in forest, agriculture, degradation and timber plantation. The B*usiness as usual* reference land use system refers to land use change as in the past; the Small improvements reference land use system is based on the B*usiness as usual* system but differs in that deforested land may not be used for palm oil production anymore. The third reference land use system *Sustainability* does not allow any deforestation even when the land area has been designated by the government to be conversion forest and no use of peatland for palm oil production. An overview of the three projections is presented in Table 1 while more details on the developments in the different reference land use categories and on the projections can be found in Appendix B.

2.4.1 Land balance (Matching of the two projections)

The land requirements for palm oil production from the four palm production expansion projections are matched with the available land as determined in the three reference land use systems in order to see whether enough land would be available to meet land demand by projected palm oil expansion. The matching follows the rules and order of land use given by the three reference land use systems.

2.5 GHG Emissions from Land Use Change Induced by Palm Oil Production

The greenhouse gas (GHG) emissions related to palm oil production are determined for LUC only. Because only LUC was studied, the emission factors do not account for emissions from the plantation, mill, transport, distribution and use. GHG emission factors for different pre-conversion land use systems are taken from literature (Wicke et al., 2008) to determine the total GHG emissions from LUC from projected palm oil production expansion in Indonesia and Malaysia. This is done by multiplying the amount of land of each land category that is converted to palm oil with the corresponding GHG emission factor.

Table 1: Overview of Reference Land Use Projections

	Reference Land Use 1	**Reference Land Use 2**	**Reference Land Use 3**
	Business as usual	*Small improvements*	*Sustainability*
Forest	• Deforestation continues as in the past	• Deforestation continues as in the past	• No more deforestation • Conversion forest is expected to be reforested
Agriculture	• Expansion continues as in the past	• Expansion continues as in the past	• Expansion occurs as projected by FAO
Degraded land	• Amount of degraded land remains constant compared to current situation (data is too uncertain to make estimations for future)		
Timber plantations	• Expansion continues as in the past		
Palm oil	• Deforested land may be used • All conversion forest may be used • Peatland may be used • Degraded land is used sometimes but is not generally economically attractive and used only as a last option [a] • Agricultural land may be displaced	• Deforested land may *not* be used • Only conversion forest *without* forest cover may be used • Peatland may be used • Agricultural land may be displaced • Degraded land is used sometimes but is not generally economically attractive and used only as a last option [a]	• Peatland and deforested land may *not* be used • Conversion forest (with and without forest cover) is *not* available • Agricultural land may *not* be displaced • Only degraded land is used

[a] - In the reference land use *Business-As-Usual* and *Small Improvements* it is assumed that degraded land is not economically attractive until all other land is used because forest land brings initial investment to the palm oil producers from extracting and selling timber, while soils are likely to be of higher quality, which also results in less fertiliser costs for deforested land than degraded land.

The GHG emission factors from palm oil production are based on the work of Wicke et al. (2008) in which GHG emissions of the production of crude palm oil (CPO) in Sabah, Malaysia are determined according to the methodology suggested by the Dutch Commission on sustainable biomass, the so-called Cramer Commission (Bergsma et al., 2006).[4] Figure 1 presents the life cycle emissions of palm oil production under different reference land use systems for Indonesia: all emissions that are caused during the establishment of the plantation (such as land clearing), production of palm oil, transportation to mill, milling the fruit to obtain CPO and transportation to for example the Netherlands are accounted for. Figure 1 shows that the breakdown of emissions by components shows that the most important source of GHG emissions is land use conversion, even when the CO_2 uptake of the oil palm plantation is accounted for. This indicates how important the choice of land for planting oil palm is (Table 2 presents the emission factors for land use change). Moreover, Figure 1 indicates that large variations in net GHG emissions are found for the different reference land use systems. For conversion of peatland, there are not only the direct emissions from LUC (carbon stock changes in biomass, soil and dead organic matter) but also the emissions from the oxidation of the organic peat soils, which are by themselves as large as the emissions from the rest of the chain. As a result, the land use case with largest GHG emissions is the case when peatland is converted to oil palm plantation. Besides peatland, natural rainforest also has extremely high emissions, while CPO production on degraded land as well as with the other management improvement options can even take up more CO_2 than emitted in the whole production chain (Table 2).

[4] While the emission calculations of Wicke et al. (2008) are based on the case study of Sabah, Malaysia, the GHG emission factors presented here were modified in order to account for differences between Sabah and Indonesia and Sabah and average Malaysia. These differences were primarily seen in yields and only affect the emissions from the plantation to the final transportation (Figure 1). Land use is not affected because average values for Southeast Asia were applied.

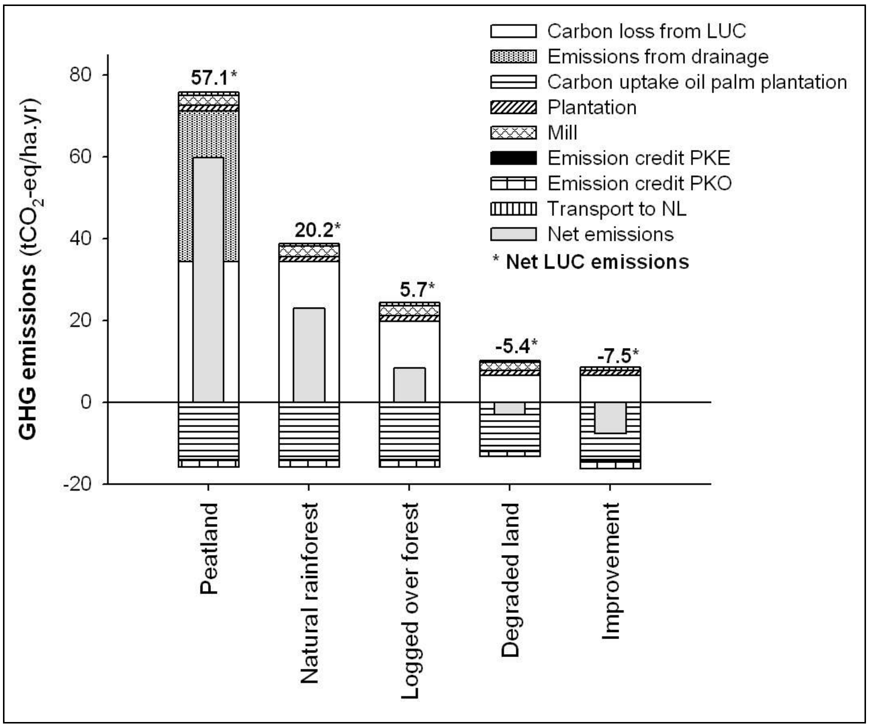


Figure 1: GHG emissions from Indonesian palm oil production
Based on Wicke et al., 2008 adopted to the situation in Indonesia
Note: Emission credits are given to palm kernel oil and palm kernel expeller because they are used outside of the system boundaries.

Table 2: Break down of GHG emissions by chain components for various CPO production cases

	Peatland forest	Natural rain forest	Logged over forest	Degraded land	Improvement
			tonne CO_2-eq / ha.yr		
Carbon loss from LUC	34.3	34.3	19.8	6.5	6.5
Emissions from drainage	36.9	0.0	0.0	0.0	0.0
Carbon credit oil palm plantation	-14.0	-14.0	-14.0	-11.9	-14.0
Total	**57.1**	**20.2**	**5.7**	**-5.4**	**-7.5**

Based on Wicke et al., 2008
Note: Degraded land assumes a lower FFB production yield and a lower biomass growth of the oil palms, which is why CO_2 assimilation at the plantation is lower than in other cases. Even though the improvement case also applies degraded land, its CO_2 assimilation at the oil palm plantation is different (i.e. the same as the other cases). This is because yields of degraded land can be improved with better management. The yield of the improvement case is here assumed to be the same yield as in the non-degraded land cases.

In Malaysia, it was often found to be the case that other plantations (mainly coconut and rubber plantations) were converted to palm oil plantations. Reinhardt et al. (2007) determine the life cycle emissions of palm oil from other plantations. For palm oil production on, for example a former coconut plantation, they determine that approximately 5 tonne CO_2 equivalent less per hectare and year are produced compared to fossil diesel. When a natural rubber plantation is converted to oil palm, this amounts to an approximately additional 5 tonne CO_2 equivalent per hectare and year compared to fossil diesel.

INDONESIA

3 LAND USE CHANGE IN INDONESIA FROM 1975 to 2005

The Southeast Asian Republic of Indonesia is administratively divided into 33 provinces and physically divided into approximately 17500 islands (Figure 2). As the world's largest archipelago and 24th largest country in the world, Indonesia covers 192 Mha of which 183 Mha are land and 9 Mha are water. In order to make an overview of LUC in Indonesia, the following sections describe each land use category and its developments over time. First, an overview of the available data is given for the following land categories: forest (section 3.1), agriculture (section 3.2), palm oil (section 3.3), peatland (section 3.4), shrubland, savannah and grassland (section 3.5), degraded land (section 3.6), and burnt and barren land (section 3.7) and then, based on this data, an overview of past LUC in Indonesia is presented and knowledge gaps and uncertainties discussed (section 3.8).

Figure 2: Map of Indonesia

3.1 Forest

Forest is the largest single land use category in Indonesia. Forestry data is distinguished into two categories: the first category refers to forest land, which is land assigned by the Indonesian government to function as forest but is not necessarily covered by forest (section 3.1.1). The delineation of land to be forest land is made "independent" of actual forest cover but is based on criteria such as "having natural vegetation, state land which has not burdened with right or controlled by a certain land user, area with bio-geophysical condition that has the function to protect hydrological condition of the lower watershed, area with natural resource phenomena which [is] suitable for conservation area and other consideration covering socio-economic, law as well as defense and security aspects" (Santoso, 2003). This implies that land, which is not covered by forests, may also be included in the category *forest land*. The second category refers to forest cover, land that is actually covered by forest (section 3.1.2). Both categories must be considered because the category "forest land" is what is primarily used by the Indonesian government to show the extent of forest, while forest cover determines how much of this forest land is actually covered by forest. In the following sections different datasets on forest land and forest cover and how both have changed over time are presented and compared to each other. Also timber plantations are treated; the results of past changes in their land use are presented in section 3.1.3.

3.1.1 Forest land

Forest land refers to land which is assigned by the Indonesian government to be "sustained as a permanent forest"; it is to function and be used as forest and serve as an economic generator on the local, regional and national level in Indonesia (Indonesian Ministry of Forestry, 2007). Forest land includes conservation forest (designated for wildlife or habitat protection), protection forest (intended to serve environmental functions such as maintaining vegetation cover or protecting watersheds) and production forest (both permanent and limited production of timber).[5] Often also conversion forest is included, which is intended to be converted to other uses (Forest Watch Indonesia and Global Forest Watch, 2002, hereafter also referred to as FWI/GFW). Forest land data could be obtained from various sources. The resulting data is presented in Table 3, while a description of the data and its sources can be found in Appendix C.

Data from the various sources shows continuity in some of the different forest classes and large variations in others. *Protection forest* has oscillated around 30 Mha, *parks and reserved forest* around 20 Mha, while *production forest* has shown a reduction from 64 million in 1984 to 57 million in 2000 and than increase again to 61 million in 2003. Much larger variations were found in the category *conversion forest*, which was approximately 30 Mha in 1984, 1986 and 1994, then decreased to 8 Mha in 1999 and 2000, and increased again to 23 Mha in 2003. It is not clear whether these variations are caused by a change in definition,[6] by having converted a large part of the conversion forest (as suggested by Forest Watch Indonesia and Global Forest Watch, 2002) or a mistake in producing the data. Moreover, for the large increase in conversion forest area in 2003 it cannot be explained whether the additional conversion forest in 2003 is caused by a different definition or from other forest land types (as suggested by FWI/GFW (2002); but this cannot be proven with the data given because the other forest classes do not decrease that significantly that they could provide this amount of conversion land) or from other land types.

Table 3: Overview of forest land in Indonesia over time

	1984*	1986*	1994*	1999*	2000*	2003
			1000 ha			
Forest land	**143269**	**140840**	**141775**	**120353**	**120400**	**133575**
protection forest	29881	29680	29649	33520	31900	30052
parks and reserved forest	18686	18250	19153	20501	23300	19876
production forest (total)	64175	62370	62973	58254	57000	60915
regular production	*No data*	31850	33402	35197	35200	35259
limited production	*No data*	30520	29571	23057	21800	25656
conversion forest	30527	30540	30000	8078	8200	22732
Percentage forest land (%)	**75**	**74**	**74**	**63**	**63**	**70**

Sources: **1984**: Whitten, 1987 (based on FAO/World Bank data);
1986: Forest Watch Indonesia and Global Forest Watch, 2002 (based on Indonesian Forestry Ministry);
1994: Contreras-Hermosilla and Fay, 2005 citing Forestry Planning Agency, 1999;
1999: Contreras-Hermosilla and Fay, 2005 citing Forestry Planning Agency, 1999;
2000: Forest Watch Indonesia and Global Forest Watch, 2002 (based on Indonesian Regional Physical Planning Programme for Transmigration, RePPProT);
2003: Indonesian Ministry of Forestry, 2007

* Figures exclude East Timor, which became independent from Indonesia in 2002.

Important to note about *production forest* is that this category presents land which may be used for logging (limited and normal production). However not all of this land is being logged at the same time and no information is available how much land (and how many times this

[5] For definitions of the different forest types see Appendix A.

[6] While all sources are referring to the same forest classes, their definitions are only stated in FWI/GFW (2002) and MOF (2007) (Appendix A). As a result, it is not clear whether some variations may also be due to differences in definitions.

land) has been logged in the past and what its current condition is. Moreover, logging often takes place illegally and it is unclear how much land has been under illegal logging in the past nor today. More information on logging will be presented in the section on direct cause of LUC (section 4.1.1).

3.1.2 Forest Cover

As previously mentioned, the Indonesian government demarcated *forest land*, which was not necessarily covered by trees let alone was forest. In contrast the term *forest cover* refers to the actual vegetation cover of the land. Differentiating between *forest land* (previous section) and *forest cover* (this section) is important for better understanding the changes that have occurred in Indonesian forests.

Data from satellite images from the Indonesian Ministry of Forestry (2007) show that in 2003 only 64% of the total forest land (as presented in the previous section) is covered by forest, 29% of the land does not have forest cover and no data is available for 6% of the land (Appendix C, Table 47). Determining the forest cover of the different forest categories applied in Indonesia shows that especially forest under regular production (logging concessions) has a forest cover of less than 60% (Appendix C, Table 47). However, according to the Indonesian Ministry of Forestry, production forest is presumed to be exploited under strict rules so that long term sustainable yields are ensured (Whitten, 1987). But if forest cover is reduced too much, not sufficient timber can be extracted and the forest becomes unproductive. A very low forest cover in production forest, therefore, demonstrates the un-sustainability of logging in Indonesia. A related aspect is that the Indonesian government decided that if forest becomes unproductive, part of it can be re-assigned to conversion forest (Kartodihardjo and Supriono, 2000). This change in classification would allow that degraded, former production forest becomes available for clear cut (extracting more timber) and for conversion to other uses such as palm oil production or timber plantations. This creates a perverse incentive to degrade production forest in order to increase the land area of convertible forest (Kartodihardjo and Supriono, 2000).

Compared to production forests, the forest cover is even lower in conversion forests where less than 50% is covered by forest (Appendix C, Table 47). Insufficient information is available to determine whether this indicates that this land was classified as conversion forest because it was already degraded forest or that the land has been deforested already as part of the conversion process. It is also important to note that protection forest and parks and other reserved forest land have a forest cover of 74 and 72%, respectively. This indicates that also protected forests do not have full forest cover. Whether this is due to the forest land designation process (that un-forested land is considered forest land) or due to logging in and conversion of protected forest, is not possible to determine with the available data.

Interesting to note is also that there is forest cover in non-forest areas. The Indonesian Ministry of Forestry estimates that in 2000 14% of land that is classified as non-forest is actually forested (Indonesian Ministry of Forestry, 2007).

Developments of Forest Cover Over Time

According to data retrieved from FWI/GFW (2002, citing Hannibal, 1950 RePPProT, undated and Holmes, 2000) and from the Indonesian Ministry of Forestry, forest cover decreased from 162 Mha in 1950 to 117 Mha in 1985 to 96 Mha in 1997 and to 85 Mha in 2003 (Table 4 and Figure 3 and Appendix C Table 48). Thus, in 1950 forest cover was found on 85% of Indonesian land, while this percentage diminished to 62%, 50% and 45% in 1985, 1997 and 2003, respectively. Data from FAO's Global Forest Assessment 2005 shows slightly higher, but comparable forest cover shares of 61% in 1990, 51% in 2000 and 46% in 2005 (FAO, 2006a) (Appendix C Table 52).

Deforestation

Based on the various sources on forest cover loss, the deforestation rate is determined (Table 4). GFW/FWI data shows a slight slowdown in average annual deforested land area in recent years but still 1.6 Mha of forest cover or 1.8% of the total forest cover is lost each year (Table 4 and Appendix C Table 51). While the absolute loss in forest cover has slightly decreased, the percentage of forest cover loss has become larger over time because the total forested area becomes smaller. Deforestation rates were on average 0.9% per year from 1950 to 1985, 1.7% from 1985 to 1997 and 1.8% from 1997 to 2003 (Appendix C Table 51). The deforestation rates for different Indonesian regions (Appendix C Table 51) makes clear that Sumatra and Kalimantan have by far the highest deforestation rates in the last recording period. Sulawesi has a very low deforestation rate in the last recording period despite having had much higher deforestation rates in the past, especially in the period of 1985 to 1997. The deforestation rates calculated from the FAO Global Forest Assessment data (FAO, 2006a) (Appendix C Table 52) are comparable to those based on data from GFW/FWI and from the Indonesian Ministry of Forestry (Indonesian Ministry of Forestry, 2007) (Appendix C Table 51). Hooijer et al. (2006) found deforestation rates (Appendix C Table 53) that were significantly smaller than those based on Indonesian ministries (Appendix C Table 51) or FAO data (Appendix C Table 52). The deforestation rate for Sumatra determined by Stibig and Malingreau (2003) (Appendix C Table 54) is very similar to that found from Indonesian government data, while the rate for all of Borneo is between the deforestation rates for Kalimantan (only Indonesian Borneo) found from Indonesian government data and by Hooijer et al. (2006). It is unclear whether the reason for this difference is simply caused by looking at a larger area in Stibig and Malingreau (2003) than in Hooijer et al. (2006) or that there are differences in forest cover.

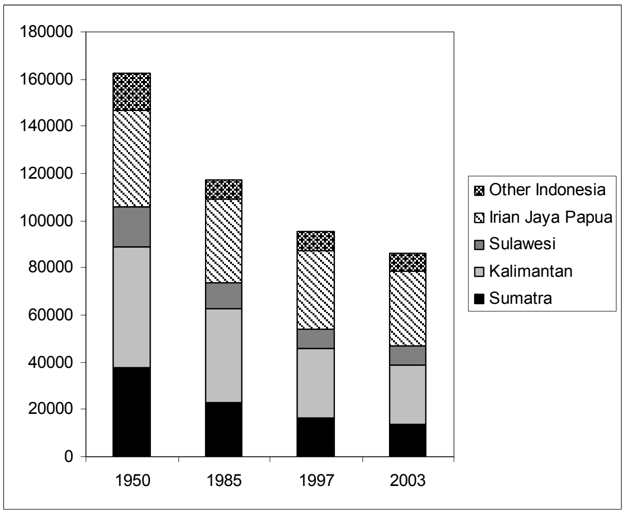


Figure 3: Deforestation in Indonesia on regional level
Source: see Table 48

The forest cover data shows that most of the Indonesian deforestation is not presented in the forest land data (see previous section). While forest land has also decreased over time, the loss in forest cover was much larger.

Table 4: Developments in forest cover in Indonesia

	1950		1985		1997		2003
Forest cover in Indonesia (1000 ha)	162290		119700		95629		85964
Percentage of total land (%)	85		63		50		45
Deforestation rates (annual average, absolute, 1000 ha/yr)		-1289		-1797		-1611	
Deforestation rates (annual averages, percentage, % lost per year)		-0.9		-1.7		-1.8	

Source: **1950**: Forest Watch Indonesia and Global Forest Watch, 2002 citing Hannibal, 1950
1985: Forest Watch Indonesia and Global Forest Watch, 2002 citing RePPProT[7]
1997: Forest Watch Indonesia and Global Forest Watch, 2002 - GFW estimates based on digital dataset from Ministry of Forestry, Government of Indonesia and the World Bank (2000)[8]

[7] Another dataset for 1985 exists that is based on GFW estimates from UNEP-WCMC, "Tropical Moist Forest and Protected Areas: The Digital Files. Version 1." Data vary slightly and cause the overall percentage of forest cover in 1985 to decrease by 1 percent point to 62%. Because of the very small difference the data is not shown here, instead it is referred to Forest Watch Indonesia and Global Forest Watch, 2002 (p. 13).

2003: Indonesian Ministry of Forestry, 2007
* Figures exclude East Timor, which become independent from Indonesia in 2002.

3.1.3 Timber plantations

Three sources present data on the land use by timber plantations in Indonesia; these are FAO's Global Planted Forests Thematic Study from 2006, FAO's Tropical Forest Plantation Areas study from 2002 and Hooijer et al. (2006). All sources result in very different estimations on land use by timber plantations (Table 5), but whether differences are really due to changes in plantation area or due to differences in definition could not be assessed.[9] However, it is known that the amount of land under timber plantations as given by Hooijer et al. refers to both existing and planned concessions and it is not possible to determine how much exists already in order to compare this data to the other sources. Also the Indonesian Ministry of Forestry presents data on timber plantations but only the change in total area per year could be obtained (Appendix C Table 55).

Table 5: Developments in timber plantations in Indonesia

	1986	**1994**	**1990**	**2000**	**2005**	**Existing and planned**[a]
Timber plantation (1000 ha)	8800	5000	2209	3002	3399	7485
Annual average growth rate (%)	-6.8		3.1	2.5		Not applicable

Source: **1990, 2000 and 2005**: FAO, 2006b (Global Planted Forests Thematic Study);
1986 and 1994: FAO, 2002b (Tropical Forest Plantation Areas)
Existing and planned timber plantations: Hooijer et al., 2006
a - Data from Hooijer et al. (2006) does not provide information regarding how much land for timber plantations already exists and how much is planned nor the time for when it is planned.

3.2 Agriculture

Total agricultural land increased between 1984 and 2003 by more than 10 Mha (Table 6). This expansion of agricultural land is evenly split for arable land (an additional 5 Mha) and permanent crops (an additional 5.5 Mha), while permanent pasture land has remained constant. The largest increase can be seen between 1984 and 1986 with an average annual expansion of 2.1 Mha and between 2000 and 2003 with an average annual expansion of 1 Mha. The increase in arable land was primarily due to increasing rice production (representing more than half of all arable land) (Figure 5) and the increase in permanent crops was primarily due to increasing palm oil production (Figure 4). In Indonesia land occupied by palm oil production has grown significantly faster than all other permanent crops (Figure 4 and Figure 7). But also the other permanent crops have been increasing.

Table 6: Historic overview of agricultural land use in Indonesia

	1975	1985	1995	2000	2005
arable land (1000 ha)	18000	19500	17342	20500	23000
permanent crops (1000 ha)	8000	8329	13045	13100	13600
permanent pastures (1000 ha)	12256	11850	11800	11177	11200
Agricultural land (1000 ha)	**38256**	**39679**	**42187**	**44777**	**47800**
Annual average change (%/y)	**0.4**	**0.6**	**1.2**	**1.3**	

Source: FAOSTAT, 2007

[8] Another dataset for 1997 exists that is based on the work of Holmes (2000) for the World Bank. Holmes did not live to provide final data for Java, Bali and Nusa Tengara, which is why this dataset is not presented here (see Forest Watch Indonesia and Global Forest Watch, 2002 (p.12)).
[9] FAO's Global planted forests thematic study states a definition for timber plantations (see Appendix A) but FAO's Tropical Forest Plantation Areas study provides no definition.

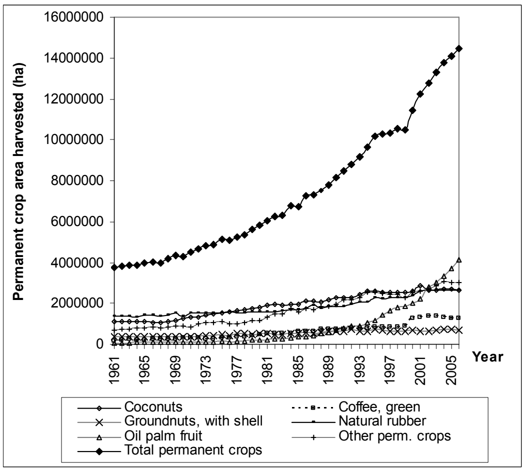


Figure 4: Composition of permanent cropland in Indonesia
Source: FAOSTAT, 2007
Note: Total area harvested - permanent crops in 2005 is 14.4 million (FAOSTAT, 2007), which is significantly higher than FAO statistics on permanent crops (Table 6). It is unclear what the cause for this discrepancy is.

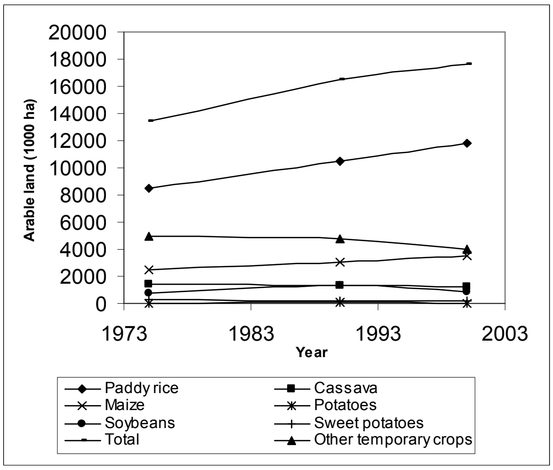


Figure 5: Composition of arable land in Indonesia
Source: FAO Agro-Maps (FAO et al., 2006)

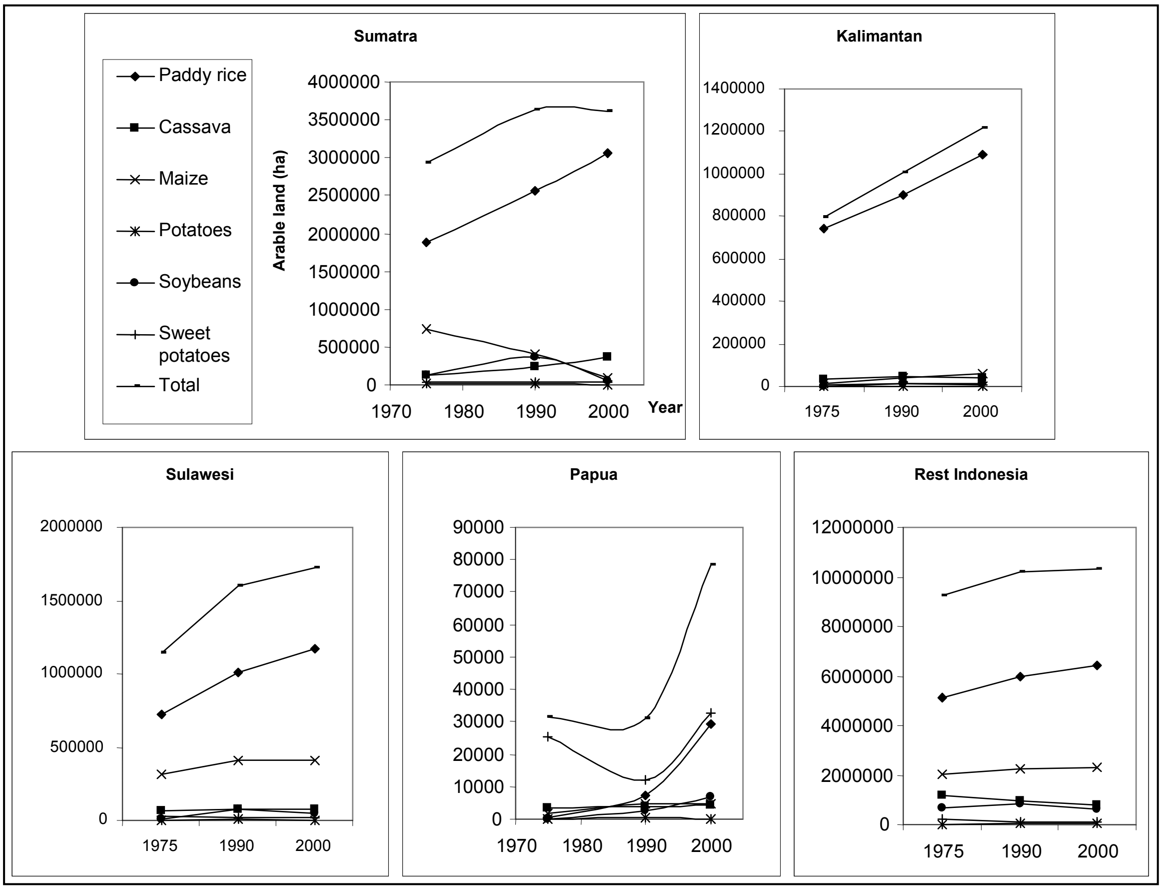


Figure 6: Composition of arable land in several regions of Indonesia
Source: FAO Agro-Maps (FAO et al., 2006)

It is interesting to note that the total agricultural land in Indonesia, as a sum of regional agricultural land (Table 7) determined by the Indonesian Bureau of Statistics (BPS) is significantly larger (15%) than the agricultural land determined by FAO (Table 6) even when BPS does not show agricultural land in Papua. Despite different terms, the definitions applied by FAO and BPS are comparable (see Appendix A) and it is not possible to determine which source represents the actually agricultural land use most realistically. Table 7 gives an indication of how temporary crops are distributed over the different regions of Indonesia.

Presented here are data from FAO Agro-Maps which cover only approximately 80% of all arable land in Indonesia.

Table 7: Regional agricultural land in 2005

	Arable land	Estates	Meadows	Agricultural land
Region		1000 ha		
Sumatra	10945	10347	481	21772
Kalimantan	9868	4835	540	15243
Sulawesi	4326	2089	427	6843
Papua	No data given	No data given	No data given	No data given
Rest	8703	1215	984	10902
Indonesia total	**33842**	**18487**	**2432**	**54760**

Source: BPS, 2007 (Agriculture, food crops, land utilisation by province)

3.3 Palm Oil

This section on the land use category palm oil is divided into three parts. First, an overview of the area under palm oil cultivation is given. Then an overview of the palm oil production volume is given, which is then followed by an overview of yields. For each section, different sources are shown and their datasets are compared.

Area

The total area under oil palm cultivation covers mature, immature and damaged palms (see Appendix A for a definition). Area with damaged crop is, however, very small – in 2005 damaged palms account for 0.5%, 1.2% and 1.3% for smallholders, private estates and government plantations, respectively (IPOC, 2005). Therefore, the area of damaged palms is not considered further. Table 8 shows the breakdown of land area under oil palm cultivation by producer type (smallholder, private estates and government), by regions (Sumatra, Kalimantan, Sulawesi, Papua, rest and total Indonesia) and by maturity level of the palms (immature and damaged vs. mature).

Table 8: Land area under oil palm cultivation in 2005: breakdown by producer type and regions

	Smallholder	Private estates	Government	Total
		1000ha		
Sumatra	**1570**	**2124**	**545**	**4240**
mature	1097	1566	509	3173
immature and damaged	473	558	36	1067
Kalimantan	**286**	**706**	**69**	**1062**
mature	200	316	53	570
immature and damaged	86	390	16	492
Sulawesi	**35**	**68**	**25**	**128**
mature	25	59	20	103
immature and damaged	10	9	5	25
Papua	**19**	**11**	**22**	**53**
mature	18	3	19	40
immature and damaged	2	8	3	13
Rest	**6**	**5**	**15**	**26**
mature	6	3	10	19
immature and damaged	0	1	5	6
Total	**1917**	**2915**	**676**	**5508**
mature	1346	1948	612	3906
immature and damaged	571	967	64	1602

Source: IPOC, 2005

Various sources give an overview of land use for palm oil production; these include FAO, Indonesian Palm Oil Commission (IPOC), the Indonesian Bureau of Statistics (BPS) and

Casson's study titled "The Hesitant Boom."[10] From all sources it becomes obvious that the land area cultivated with oil palm has increased significantly in the last thirty years (Figure 7 shows the developments of total area planted with palm oil vs. the mature area according to FAO data), but the mentioned studies vary in the exact amounts of land occupied by palm oil production. For example, while FAO lists an area harvested of 3.7 Mha for 2005 (FAOSTAT, 2007), the Indonesian Bureau of Statistics refers to 3.6 Mha (Indonesian Bureau of Statistics, 2007) and the Indonesian Palm Oil Commission to 3.9 Mha (IPOC, 2005) for the same year (see Appendix D for a compilation of data). Even though this hardly affects the share of palm oil in the total Indonesian land use, these discrepancies in data illustrate the uncertainties in the data and possibly differences in definitions, i.e. age of plantation from when it is considered mature. However, no information could be obtained on what definitions for area harvested / mature palms were applied.

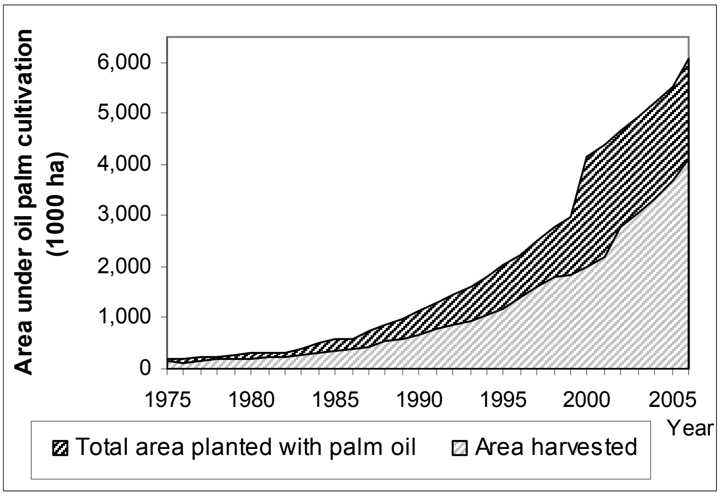


Figure 7: Area planted with oil palm vs. area harvested
Source: Area harvested: FAO 2007;
Area planted with oil palm: Indonesian Ministry of Agriculture, 2007

Regional cultivation
Most of the growth in land use for palm oil production has taken place in Sumatra, but since the late 1990's also the growth in Kalimantan has been fast and large (Table 9). As shown in Table 8, in 2005 most of the land area under oil palm cultivation took place on Sumatra, where 77% of all area planted with palm oil was found and to a lesser extend on Kalimantan with 19% of the total oil palm area.

Table 9: Land area under palm oil cultivation by Indonesian regions 1975-2006

	1975	1990	1997	2000	2005	2006
			1000 ha			
Sumatra	188	1000	1978	3162	4240	4583
Kalimantan	0	80	409	809	1062	1268
Papua	0	10	19	48	53	62
Sulawesi	0	20	88	120	128	135
Rest of Indonesia	1	16	22	19	26	28
Indonesia	**189**	**1127**	**2516**	**4158**	**5509**	**6075**
Annual average change (%)	**13**	**12**	**18**	**6**	**10**	

Source: Indonesian Ministry of Agriculture, 2007

Production

The same source that presented data on the land use by palm oil production (FAO, Indonesian Palm Oil Commission (IPOC), the Indonesian Bureau of Statistics (BPS) and Casson) also present data on palm oil production, which again varies from each other (Figure 8 and Appendix D). FAO and Casson present identical number until 1994, after which

[10] The study of Casson was conducted in 2000, which is why the data is not included here for comparison with other sources.

FAO data is slightly higher. BPS presents much lower production of palm oil while IPOC shows higher production for some years (1999-2002 and 2004) and lower production for other years (2003 and 2005).

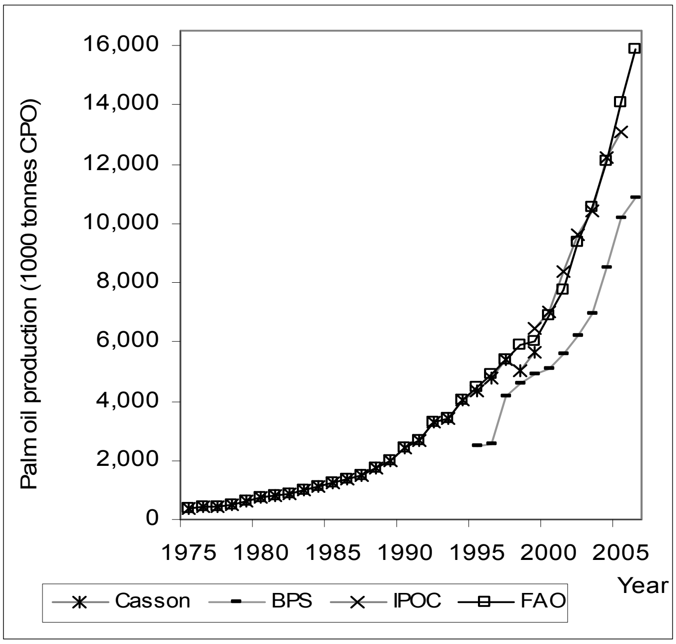


Figure 8: Production volumes of palm oil

Source: Casson 2000, citing Indonesian Bureau of Statistics (BPS): 1975 to 1999;
Indonesian Bureau of Statistics, 2007: 1999 to 2006;
IPOC, 2005: 1999 to 2005;
FAOSTAT, 2007: 1975 - 2006

Regional production

While 77% of all land use by palm oil production was found in Sumatra and 19% in Kalimantan, Sumatra produced 84% of all palm oil in Indonesia and Kalimantan 13% (Table 10). The difference in percentages from land area and production can be contributed to differences in yields (Table 12).

Table 10: Palm oil production in 2005: breakdown by producer type and regions

	Smallholder	Private estates	Government	Total
		1000 tonne		
Sumatra	3295	5817	1871	10982
Kalimantan	453	1063	150	1666
Sulawesi	67	180	57	304
Papua	44	8	51	104
Rest of Indonesia	14	12	29	55
Total Indonesia	**3873**	**7080**	**2159**	**13111**

Source: IPOC, 2005

Yield

The differences in production are also reflected in yield differences. For Casson no yield is determined because total land area is presented rather than area harvested (with which yields are determined). Yields for the other source can be found in Appendix D and an overview is given in Table 11. While the yield appears to stagnating since the 1980's at around 3.5 t ha^{-1} y^{-1}, the yield has increased in recent years again. In 2005 the yield was already 3.8 and in 2006 3.9 t ha^{-1} y^{-1}.

Table 11: Yield developments in Indonesia

	1975-1979	1980-1989	1990-1999	2000-2005
		tonne / ha.yr		
Average yield Indonesia	3.1	3.6	3.5	3.5

Source: FAO STAT data on harvested area (oil palm fruit) and production palm oil (CPO)

Regional yields are determined from the IPOC data from 2005 (Table 12). It can be seen that Sumatra with the highest overall production and land use for palm oil has also the highest yield compared to other regions. In general it can be seen that private estates have the largest yields, but this is only slight in the case of government production and large in the case of smallholders.

Table 12: Palm oil production yields in 2005: breakdown by producer type and regions

Producer type	Smallholder	Private estates	Government	Total
Region		tonne/ha		
Sumatra	3.0	3.7	3.7	3.5
Kalimantan	2.3	3.4	2.8	2.9
Sulawesi	2.7	3.1	2.9	2.9
Papua	2.5	2.7	2.6	2.6
Rest of Indonesia	2.4	3.4	3.0	2.9
Total Indonesia	**2.9**	**3.6**	**3.5**	**3.4**

Source: IPOC, 2005

3.4 Peatland

Peatland Forest

Peatland in Southeast Asia, originally covered by forest, has also been affected by deforestation (UNDP Malaysia, 2006). Overall there is an area of 22.5 Mha of peatland in Indonesia (Hooijer et al., 2006), with literature ranging between 17.8 and 20.1 Mha (Rieley and Page, 2005) to even 27 Mha (Rieley and Page, 2005 citing Radjagukguk, 1992). The distribution of peatland in Indonesia is shown in Figure 9. This peatland can be divided by peat depth, ranging from less than 1 metre depth to over 10 metres (Figure 10) where 42% of all peatland in Indonesia has a peat thickness of over 2 metres (Hooijer et al., 2006).[11]

Table 13 shows the changes in forest cover of peatland. For all of Indonesia the deforestation rate on peatland amounted to 1.3% per year with the largest deforestation rate having taken place in Kalimantan. Depending on the source of the general deforestation rates, deforestation on peatland is worse than the general deforestation rate (FAO, GWF/FWI, Indonesian Ministry of Forestry (MOF), Table 52) and better than the general deforestation rate as determined by Hooijer et al.

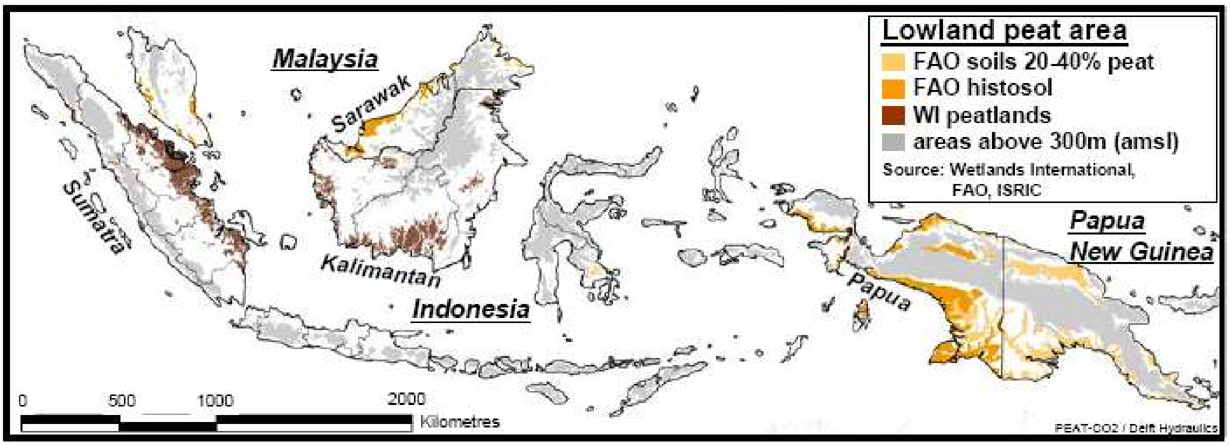


Figure 9: Low land peat area
Source: Hooijer et al, 2006 Peat-CO2 / Delft Hydraulics

The International Mire Conservation Group provides slightly different estimates on how much peatland has been converted to other uses than forest: for Sumatra 37% of peatland has been converted to other uses, 20% of land in Kalimantan, 2% in Irian Jaya, 23% in Sulawesi

[11] Peat depth could not be compared to data from other sources because no additional information could be obtained from literature.

and overall for Indonesia 18% (International Mire Conservation Group, 2004 citing Rieley et al. 1996b and Rieley et al. 1997).

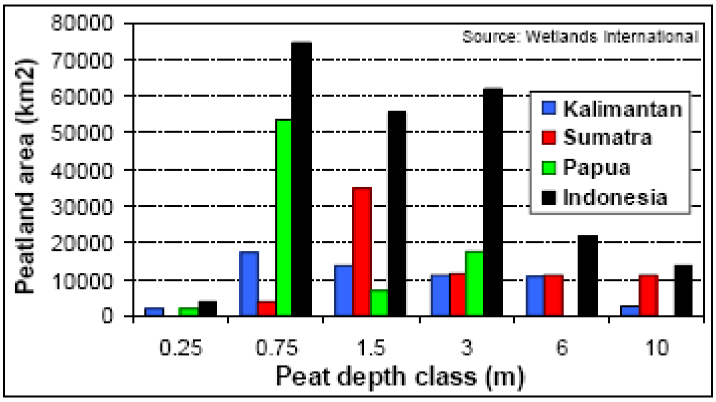


Figure 10: Peatland area by peat depth classes
Source: Hooijer et al., 2006

Table 13 Peatland forest cover changes in Indonesia

	Peatland area	Peatland forest cover	Peatland forest cover	Peatland forest cover loss	Percentage of original peat forest cover
		1985	2000	1985-2000	**2000**
	1000 ha	1000 ha	1000 ha	%/y	%
Sumatra	6932	5407	3605	-1.8	52
Kalimantan	5838	5709	3386	-1.9	58
Papua	7554	6043	5439	-0.5	72
Rest of Indonesia*	2199	-	1342	-	61
Total Indonesia	22523	18244	13739	-1.3	61

Source: Hooijer et al., 2006 citing Wetlands International and FAO for peatland area; GFW for peatland forest cover 1985; and GLC2000 for peatland forest cover 2000
* Including Sulawesi, for which no separate data was available

Logging on peatland
Based on data about existing and planned concession, Hooijer et al., 2006 state that 10% of all logging concessions in Indonesia are on peatlands, that is 2 of the 24 Mha of logging concessions.[12] Peatland is generally less attractive to logging companies than non-peat forest land because drainage is required before logging can be started, which causes the initial investment costs to rise. However, when these drainage canals are established, the transportation of the logged wood can take place via these canals, which is easier and cheaper than road transport.

Timber plantations on peatland
Based on available concession data, Hooijer et al. (2006) state that of 7.4 Mha of timber plantation concessions (section 3.1.3) 2 million are located on peatland.[13] This represents 27% of all timber plantation concessions in Indonesia are on peatland, while peatland accounts for only 15 % of the total land area of Indonesia.

Palm oil on peatland
Hooijer et al. (2006) also determined the existing and planned oil palm concessions. They found that of the existing and planned 10.3 Mha of palm oil concessions 2.8 Mha are located on peatland,[13] thereby representing 27% of all palm oil concessions while covering 14% of the total peatland area in Indonesia (Hooijer et al., 2006). Most of these concessions are

[12] It must be noted that Hooijer et al. (2006) determined **existing and planned** concessions and that only Kalimantan, Sumatra and Papua are included. Including planned concessions may explain why the total area of logging concessions is so much lower than the total logging concession area in 2000, which was 69 Mha (Forest Watch Indonesia and Global Forest Watch, 2002) but may also indicate that logging concessions are to be reduced in the future.
[13] Note that the data from Hooijer et al. (2006) covers **existing and planned** concessions and includes only Kalimantan, Sumatra and Papua and that it is unclear how much is existing, how much is planned and for which year it is planned.

concentrated in Sumatra and Kalimantan, with only a small oil palm concession area in Irian Jaya (Papua). How much of the concession areas found by Hooijer et al. already exist, how much are planned and whose plans these are is not possible to determine from the data presented by Hooijer et al. (2006).

3.5 Shrubland, savannah and grassland

According to the Global Land Cover Characteristics Database (GLCCD), shrubland, savannahs and grasslands made up 8 % of Indonesian land area in 1992/93, which was mainly savannah and grasslands (Table 14).[14] It is unclear how these land areas have changed over the past 15 years.

Table 14: Shrubland, grassland and savannah in Indonesia -1992/1993

	1992-93
	1000 ha
Shrubland	72
Savannah	10652
Grasslands	4844
Total	**15568**
Percentage of total land area	**8%**

Source: Earthtrends, 2007c citing GLCCD

Imperata grassland

Imperata cylindrical L. (also known as alang-alang in Indonesia) is the most common weed in the tropics, where it invades land that was previously inappropriately managed and then abandoned (Syahrinudin, 2005). In literature, *Imperata* grasslands in tropical Asia are often associated with degraded land (Syahrinudin, 2005; Garrity et al., 1997) and it is unclear whether the degraded land data presented below in Table 14 account for this type of grasslands. The most comprehensive study with overviews of *Imperata* grassland area and distribution in Asia (Garrity et al., 1997) indicates that in Indonesia at least 8.5 Mha of *Imperata* grassland exists, making up 4.5% of the total land.[15] In Indonesia most of the *Imperata* grasslands occur in the form of sheet Imperata, continuous grassland areas of 10 000 hectare or more (Garrity et al., 1997). Garrity et al. (1997) suggest that the land area covered by *Imperata* grassland is increasing, however only little is known at what rates and where. Additionally, hardly any information is available on the (human induced and natural) developments of *Imperata* grasslands in the past.

3.6 Degraded land

There is no clear, universally agreed upon definition of degraded land. Here the definition of the Food and Agriculture Organisation of the UN (2007a citing ISO, 1996) is applied which states that "land which due to natural processes or human activity is no longer available to sustain properly an economic function and / or the original ecological function." Various literature sources on the amount of land affected by degradation show a large range of degraded land. The largest amount of degraded land is determined by the Indonesian MOF (74 Mha) (Indonesian Ministry of Forestry, 2007), which is followed by GLASOD (31 Mha) (FAO, 2008), then WWF (18 Mha) (personal communication with A. Harrison, WWF Scotland) and finally Casson (12 Mha) (Casson, 2000) (see also Appendix C for a description of this data and its sources). The main cause of this difference is likely to lie in the definitions applied. However, these definitions could in many cases not be obtained and, therefore, not further analysed (see also Appendix C).

In some studies degraded land was set equal to land that had been invaded by grasses (i.e. *Imperata cylindrical* L.). Grasslands are not included in the category of degraded land in this study as it was already treated in the previous section "shrubland, savannahs and

[14] Scientific teams assessing the accuracy of GLCC found that a given area agreed with classification of GLCCD in only 60 to 80% of the cases (Earthtrends, Technical notes to Land Area Classification by Ecosystem Type, 2007).

[15] The figure of *Imperata* grassland stated by Garrity et al (1997) does not match the data from GLCCD as cited by Earthtrends (2007). The reasons for these differences are not clear.

grassland." However, it needs to be pointed out that this is likely to cause overlaps between the category degraded land and the category grassland. But due to the lack of definitions of degraded land it was not possible to estimate the size of such an overlap.

3.7 Burnt and Barren Land

Land affected by fires has received a large amount of attention in recent years because of the extremely large extent of fires in 1997/98 and the associated large effect on human health and the economy. Siscawati (undated) cites Bobsien and Hoffmann (1998) to present data on land areas affected by fire from 1982 to 1998.

Table 15: Land affected by fires

Year	Land area affect by fires ha	Main area
1982 / 1983	3.5-3.7 million	Kalimantan/Sumatra
1986	Approx. 1 million	Sumatra/Kalimantan
1991	Approx. 500 thousand	Kalimantan/Sumatra
1994	300 thousand	Kalimantan/Sumatra
1997	1.7-2 million	Kalimantan/Sumatra/Irian Jaya/Java/Maluku/Sulawesi
Jan. – Apr. 1998	283 thousand	East Kalimantan

Source: Siscawati (undated) citing Bobsien and Hoffmann, 1998

Contrary to these findings, GLCCD suggests that there is no land affected by fire in 1992/93. However, GLC2000 estimates a total land area affected by fires and together with barren land in 2000 of 11 Mha,[16] while the Global Forest Assessment of the FAO estimates a 122 000 hectare of land have been affected by fire (FAO, 2006a).

Several problems in the presented data are found: A problem of the GLC2000 data is caused by the combination of burnt and barren land as it is unclear how much of this category is barren but not because of fires. Moreover, there is a problem in how severely a land area is affected by fire, i.e. lack of information on the length of the recuperation period and the subsequent management activities. Also, underground peat fires, which can exist for a long time after aboveground fires are stopped, are not accounted for in the data presented above. As a result of these uncertainties, burnt land is not included in the overview of LUC (section 3.8). As fires are also a cause of LUC, the reasons for and effects of fires are presented in section 4.1.5.

3.8 Overview of Past Land Use Change

Based on the data presented in the previous sections, an overview of LUC over the past 25 years (1975 to 2005) is made. This overview of LUC in Indonesia is based on many uncertainties in and unavailability of data. Therefore, the following assumptions are made in order to make an overview of LUC in Indonesia possible (Figure 11):

- *Forest cover* data is based on the FWI/GFW data given for 1950, 1985, 1997 and 2003. Forest cover in all other years is based on deforestation rates determined from this data.
- For *shrubland* and *savannah* no information over time could be found so that, for this overview, it is simply assumed to remain constant.
- *Grassland* is assumed to be 4.8 Mha in 1992 based on the results of GLCCD presented above and 8.5 Mha in 1998 based on the study by Garrity et al. The grassland area before 1992 is based on the growth rate as between 1992 and 1998. Because of the very rapid changes between 1992 and 1998 and no other information for the period after 1998, it is assumed that the grassland area remained constant after 1998.
- Data on *arable land, permanent crops without palm oil* and *permanent pastures* are taken from FAOSTAT where permanent crops without palm oil is calculated by taking

[16] GLC2000 categories take burnt land together with barren land and sparse vegetated land and it is unclear how much land actually is barren or sparsely vegetated for other reasons than fires.

the FAOSTAT land data for permanent crops and subtracting the land area for palm oil production.

- Data for *mature oil palms* is taken from FAO area harvested statistics as presented above, while *immature oil palms* is determined by taking the difference between area harvested (FAO STAT) and total area (as presented by Casson for 1975 to 1999 and the Indonesian Ministry of Agriculture for 2000 to 2005).
- *Timber plantation* data used in the overview are based on total area planted and average growth rate found in the FAO Global Planted Forests Thematic Study (FAO, 2006b).
- *Degraded land* in 1980 is set equal to the land area categorised *dominantly very severely degraded* under GLASOD. This amounts to 7.5 Mha. But, considering that the category *dominant* refers to a percentage cover in each polygon of above 50 to 100%, actually only (on average) 75% of the land area should be considered degraded. Therefore, degraded land in 1980 is assumed to amount to 5.6 Mha. The 1998 value is taken from Casson (2000) as approximately 12 Mha. It must be noted that these are very rough data and only used to get an idea of the changes. Data from Indonesian MOF is not included as very large overlaps with other land categories are likely but cannot be defined.
- Besides the different land use categories, there is also some land left over, here called "*rest*" which does not fall in either of the categories. It is uncertain what type of land it is and how it is used. Part of this land is likely to burnt land, which is not included in the overview due to the very uncertain nature of the data found in literature. But this rest land may also be deforested land lying idle, or other degraded land not accounted for in the statistics.

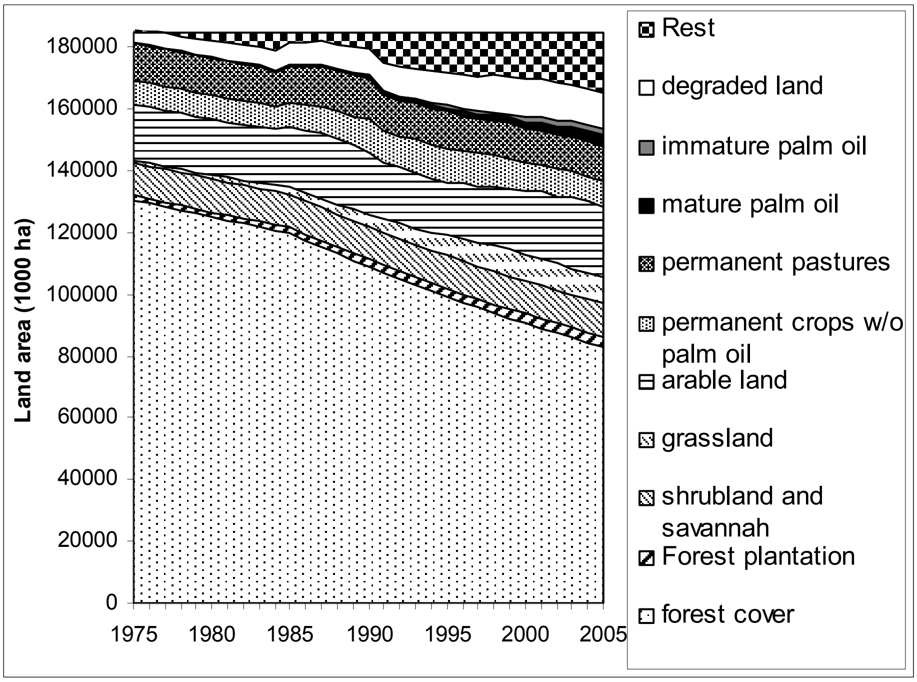


Figure 11: Overview of past land use change in Indonesia: 1975 to 2005

The uncertainties and resulting assumptions should be kept in mind when interpreting Figure 11. Despite these uncertainties, however, such an overview is valuable for making the trends of the past LUC more visible.

Figure 11 shows once more the significant loss in land covered by forest. Moreover, it can be seen that arable land, particularly land under rice production, palm oil and timber plantations have grown over time. *However, all increases in agricultural land (including palm oil) and timber plantations together do not explain all of the forest cover loss.* Degraded land shows significant increases but the large uncertainties in data do not allow clear conclusions about their precise changes in degraded land over time.

The overview of past LUC in Indonesia offers two important messages: Firstly, the large decrease in forest cover cannot be explained by a single factor but also palm oil expansion combined with other agricultural production expansion and timber plantation expansion cannot explain all of the deforestation. Thus, it is clear that also other drivers must have been involved in deforestation, which cannot be seen from the land use data presented above (and are investigated further in the following chapter). Secondly, degraded land has strongly increased in the past but detailed information of this category is too scarce to draw precise conclusions about the severity of degradation.

4 CAUSES AND DRIVERS OF LAND USE CHANGE IN INDONESIA

In the previous chapter it was found that the loss of forest cover is the single largest change in land use in Indonesia. But the cause for this change could not simply be attributed to an increase in land use by any one other land use category. In this chapter the direct causes and underlying drivers of this change will be analysed. The main focus will be placed on the reasons for deforestation as this is the single largest change in land use and because many of the causes of deforestation represent at the same time also changes in other land use categories. A good example of this phenomenon is the expansion of agricultural land use that causes deforestation but that is also a change in land use in itself.

The causes of *global* forest decline as presented by Geist and Lambin (2002) serve as a good overview of the causes of deforestation and general LUC in Indonesia (Figure 12). Geist and Lambin determine three main proximate causes (infrastructure extension, agricultural expansion and wood extraction) and five underlying causes (demographic, economic, technological, policy and institutional and cultural) of global forest decline (Figure 12). Geist and Lambin (2002) explain that there is no single cause for deforestation but rather a web of direct causes and underlying factors, where one or more underlying factors can influence one or more direct causes.

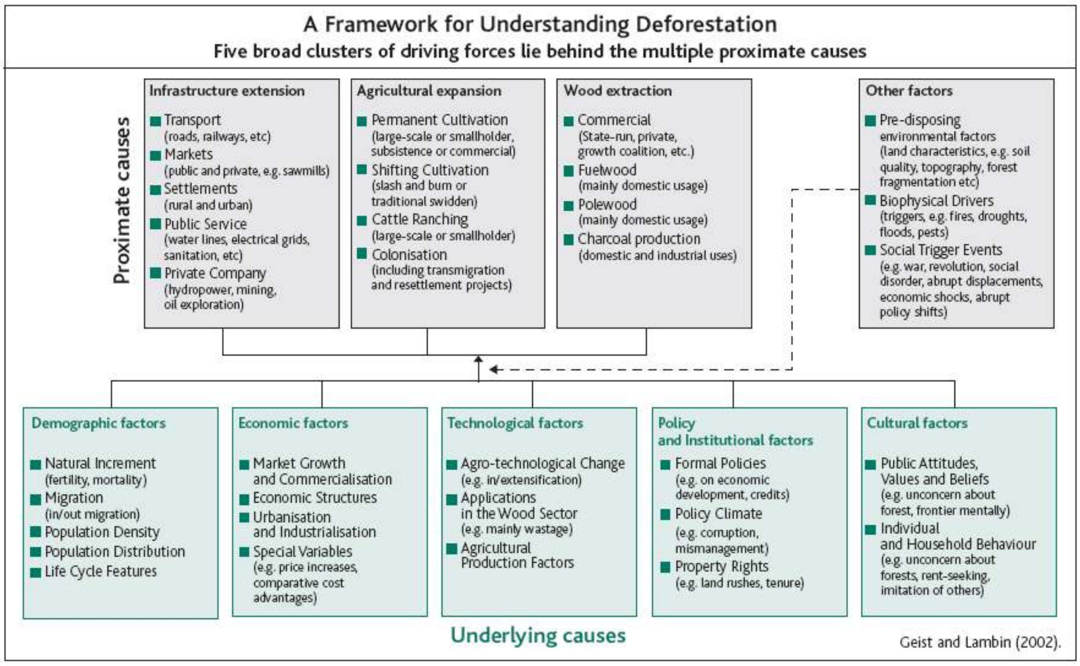


Figure 12: Causes of forest decline
Source: Geist and Lambin, 2002

In order to get a better understanding of the factors that cause LUC in Indonesia, it is here also useful to divide factors into *direct causes* (i.e. logging and the resulting loss of forest) and *underlying drivers* of these causes (i.e. increased demand for timber in society). In the following the direct causes and underlying drivers - that literature found to be most relevant for Indonesia - are described. First the direct causes are illustrated (section 4.1) and then the underlying drivers are identified, as far as possible quantitatively assessed and then linked to the direct causes (section 4.2). An overview of the various causes and drivers and their contribution to LUC is presented at the end of this chapter (section 4.3).

4.1 Direct Causes of Past Land Use Change

Direct causes of LUC are activities and actions that directly change land use (Geist and Lambin, 2002). Generally, there are multiple direct causes of LUC as is also the case for Indonesia. The data presented in the previous chapter indicates that logging (directly causing loss of forest cover and degradation), palm oil expansion, other agricultural crop expansion, developments of timber plantations and fires are important direct causes of LUC in Indonesia. But also infrastructure extension is a direct cause of LUC, which cannot be seen from the LUC data presented earlier but that does require attention here. Each of these direct causes is explained in more detail below.

4.1.1 Logging

Logging of trees for timber purposes and for the conversion of forest to other land use types is directly linked to forest cover loss. This is mainly due to trees being extracted. But extraction also results in the destruction and resulting degradation of the forest by the large machinery and equipment applied for timber extraction.

Logging concessions, the license to harvest timber in a certain forest area, are delineated and handed out by the Forestry Department. The category "production forest" includes land that is handed out for timber concessions and land that may be used for logging in the future. However, comparing the total land area of timber concessions with the forest area actually designated as production forest it can be seen that in 1983, 1997 and in 2000 the timber concession area exceeded the total area of production forest (Table 16). Only for 1997 literature states that timber concessions were also handed out on conversion forest land. However, it is not clear whether this explains the larger timber concession area in other years as well or whether these may actually be located on protection and conservation forest land.

Table 16: Timber concession area compared to production forest area

Year	Timber concession area Million ha	Production forest area Million ha	Source
1983	65	64	Siscawati, undated
1997[a]	69	59	Kartodihardjo and Supriono, 2000
Early 2000	55	57	FWI/GFW 2002
Mid 2000 [b]	69	57	FWI/GFW 2002

[a] – conversion forest is also used for concessions (Kartodihardjo and Supriono, 2000)
[b] – Mid **2000**: 69 Mha total concession area: 34 Mha operating, 30 Mha expired concessions but land had not be returned to government and 5.5 Mha had been returned to government

Besides legal logging in concession areas, there is also illegal logging, which is estimated to be much larger in terms of production volumes than legal logging (Otsamo, 2001). Otsamo (2001) describes illegal logging in Indonesia in 1998 in the following:

> "According to recent estimates, most of the wood logged today is illegal. In 1998 for example, the official production of round wood in Indonesia was just over 21 million m^3. However, total production was estimated at 78 million m^3. The shortfall was met by unrecorded production, the majority of which is illegal logging (European Commission 2000). Defining 'illegal logging' is somewhat complicated in Indonesia, since many stakeholders are involved in it. In addition to the demands of the traditional plywood industry, illegally logged wood constitutes a considerable proportion of the raw material of the major new pulp mills in the country (Barr 2000)" (Otsamo, 2001).

Contreras-Hermosilla and Fay (2005 citing Litski, 2004) confirm this by presenting similar findings for 2002: Officially authorised log production was approximately 10 million m^3 of wood but the actual log equivalent of processed wood is estimated to exceed 50 million m^3 in the same year (Contreras-Hermosilla and Fay, 2005 citing Litski, 2004). This creates an illegal supply which is four times as large as the legal supply.

Comparing the annual amount of timber extraction with the sustainable yield of Indonesia further demonstrates that logging triggers forest cover loss and forest degradation in Indonesia. Sunderlin and Resosudarmo (1996, citing World Bank 1995) state that, in the beginning of the 1990's, forests in Indonesia "are being logged at a rate of roughly 40 million m^3 per year, whereas the 'sustainable' rate recommended by the Ministry of Forestry is 22 million m^3 per yr." As shown above, more recent data shows that timber extraction has surpassed this sustainable extraction rate even more than in the past, again indicating the unsustainability of logging in Indonesia.

4.1.2 Palm Oil Expansion

Palm oil production and its land use have increased considerably in recent years (section 3.3). Between 1978 and 2003 the land area under palm oil production increased by 4.6 Mha while forest cover decreased by 41 Mha. Thus, at most, palm oil may be made responsible for 11 % of the deforestation over this period. When looking at a shorter, recent period, 1997 to 2003, then it can be seen that 2.6 Mha new land has been converted to palm oil while 9.7 Mha of forest cover was lost. Thus, palm oil may be made responsible for at most 27% of all deforestation. This percentage is likely to be lower as also other land types have been converted to palm oil, such as degraded land and other plantations (Pagiola, 2001). But it is difficult to determine the exact percentage as more specific data on the type of land that was converted to palm oil production is not known. Despite this lack of information and making a very simplistic comparison between the two time periods, it can be concluded that it is likely that palm oil has had a larger role in deforestation in recent years than in the past.

One important factor of palm oil expansion in Indonesia is the increasing world demand for palm oil in the past, which in turn can be partially explained by the lower price of palm oil compared to other vegetable oils. The increasing demand and the lower price are underlying drivers for palm oil production expansion and are described more in section 4.2.

4.1.3 Other Agricultural Land Expansion

As presented in the chapter on LUC in Indonesia, agricultural land has increased significantly in the last 30 years (see section 3.2). Most important to mention here is the production of paddy rice in Indonesia. Rice is the most important staple of Indonesian diet while Indonesia is also the third largest producer of rice in the world in 2005 (FAOSTAT, 2007). The area under rice production increased from 6.9 Mha in 1961 to 11.4 Mha in 2006, while the total production volume increased by 12.1 million tonne to 54.4 million tonne in the same time period. Even though the land expansion occurred at a factor of nearly two, the growth in the amount of rice produced was more than fourfold. Thus, increased agricultural productivity weakens the effect of agricultural expansion, as much more land would have been required if yields had not increased. The increased production of rice and other agricultural crops is caused by the underlying driver of population growth and the resulting increased food demand (see section 4.2).

Moreover, Indonesia has also become an exporter of many more foods than in the past, which further explains agricultural expansion. In the 1960's Indonesia primarily exported coffee, rubber, tea, tobacco and species. In 2005 all these products were exported in higher quantities and also other products were exported such as for example cocoa beans, coconut, palm oil, palm kernel oil (FAOSTAT, 2007).

4.1.4 Timber Plantations

The previous chapter has shown that timber plantations have been increasing in the past but still remain a small part of all LUC (section 3.1.3). Timber plantations are increasing mainly because there is more demand for timber, while the government is trying to reduce logging in natural forests. This underlying driver of increasing timber demand is dealt with in section 4.2.

4.1.5 Forest and Peatland Forest Fires

In the previous chapter it was shown that it is difficult to determine the exact amount of land that is affected by fires (section 3.7). However, it is not questioned that forest fires are a direct cause of forest cover loss. And it is clear that forest fires also are a result of deforestation and forest degradation (Siscawati, undated). The causes of fires in Indonesia as described by Siscawati (undated) are fourfold:

1) The easiest method for clearing forest is to burn the standing biomass. While this is not allowed anymore, it is still often done;
2) Logging and conversion of peatland to other uses dries the land and makes it more susceptible to fires and the spreading of fires. The fires in 1997/1998 were worsened by a very dry period, effects of the then occurring El Niño phenomenon;
3) Conversion from naturally occurring species to more flammable species on timber plantations;
4) Another important cause is land tenure conflicts, which have brought about arsonists.

For fires between July to September 1997 Siscawati (undated citing Bobsien and Hoffman 1998) suggests that 43% of fires were located on timber and tree crop plantations, 37% on production forest sites, 12% in peat swamp areas (no more information is available on whether this was deforested or logging, timber or palm oil concessions) and 8% in swidden agriculture areas.

4.1.6 Infrastructure Extension

Another direct cause of forest decline is the extension of infrastructure, which requires the clearing of land and through which deeper access into the forests are given. As a result, logging operation and agricultural activities can move further into the forest without suffering from more difficult and more expensive transportation of timber and agricultural goods to the markets (CIFOR, 2007). However, it must be noted that it is also often the case that logging companies make roads so that timber is more easily and cheaply transported to the markets. After road expansion for logging, settlers have easier access to previously remote areas on which they can establish swidden agriculture.

For Indonesia, however, it is not possible to determine whether roads where constructed first in order to facilitate logging or whether logging was followed by infrastructure extension for other activities. However, Sunderlin and Resosudarmo (1996) found for all of Southeast Asia that it is often the case that after an area is logged intensively, it is converted to agriculture and that it is not the agriculture that comes in first and causes deforestation. In general it could be seen that national infrastructure (in terms of road length) was extended (Figure 13). Unfortunately this data could only be obtained for the national level, while data on regional level could not be found.

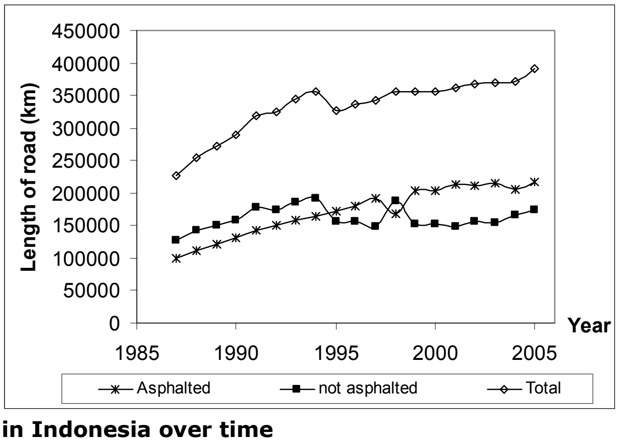


Figure 13: Length of Road in Indonesia over time

4.2 Underlying Drivers of Past Land Use Change

Underlying drivers are "fundamental social processes" that underpin the direct causes (Geist and Lambin, 2002). As with the direct causes of LUC, also the underlying drivers are multiple. An underlying factor can drive various direct causes and various underlying factors together can also drive only one direct cause. The main underlying drivers of LUC in Indonesia are population growth, economic growth, policy and institutional factors, and agricultural and forest prices. In the following these drivers of LUC are described and their relationships to the direct causes are determined.

4.2.1 Population Increases

In Indonesia, population has increased from 119 million people in 1971 to 206 million people in 2000. The largest growth in population was seen primarily in Java (in Figure 14 under the category "Rest" of Indonesia). Population growth is linked to LUC by the additional land that is required for living, food production and resource extraction (direct causes of LUC). While there is no doubt that increasing population density plays a role in deforestation – there is an inverse correlation between population density and forest cover - it is not clear whether the population increase is actually the main cause (Sunderlin and Resosudarmo, 1996). Sunderlin and Resosudarmo (1996) explain that in Southeast Asia it is often the case that after an area is logged intensively, it is converted to agriculture and that it is not the agriculture that comes in first and causes deforestation. Moreover, there are other variables not yet accounted for, such as technological change, demand for agricultural productions and growth in infrastructure (Sunderlin and Resosudarmo, 1996).

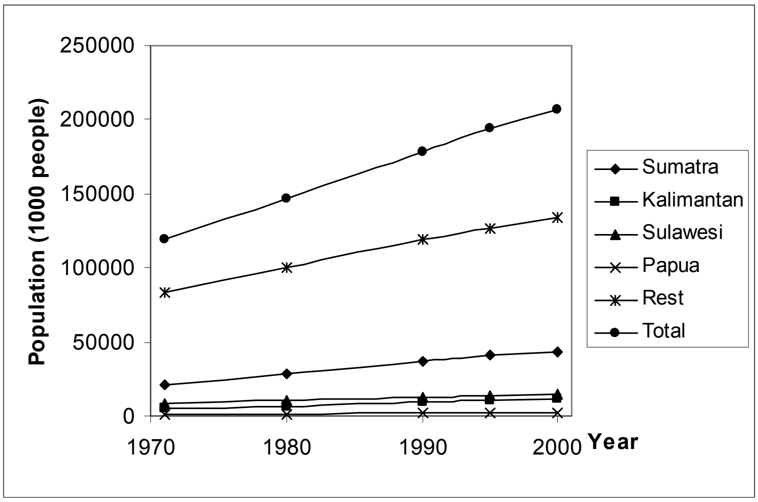


Figure 14: Population developments in Indonesia and its regions

Regional population growth/changes can also be caused by government sponsored transmigration and "spontaneous" (not government assisted) migration to the outer islands. The Indonesian government sponsored transmigration programs for moving inhabitants of Java and other islands with high population densities to the outer islands. According to Sunderlin and Resoudarmo (1996) transmigration affects forests in three ways: directly by removing forest cover for establishment, indirectly by using and converting other forest land because given lands produces insufficient income, and in an induced way by displacing neighbouring non-transmigrant households, which then have to start using other land. However, while forest land has been cleared directly in relation to transmigration projects, literature states that this plays only a minor role in forest loss (Fearnside, 1997; Whitten, 1987). Indirectly, transmigration may have caused more forest loss as many of the transmigration projects were located on poor quality soils so that yields of agricultural crops were generally low and farmers needed additional income, which is often met by illegal logging or extension of land into forest areas (Sunderlin and Resosudarmo, 1996). However, more information and data regarding this phenomenon is lacking. According to Whitten (1987), the effect of spontaneous transmigration is more important than direct impacts because it far outnumbers the government-sponsored migrants. It is estimated that for each government-sponsored migrant an additional two spontaneous settlers have moved

(Whitten, 1987). With this spontaneous migration, also the land and resource requirements increase strongly.

An additional aspect of population as an underlying driver of LUC is the link between population growth, increased food demand and the associated increasing demand for land for food production (a direct cause of LUC). The increasing food demands by a growing population can be seen in the expansion of almost all agricultural crops (section 3.2). However, the expansion in land for food production was not proportional to population increases. This may be caused by increased yields observed for many food crops and particularly for rice and/or by food imports (food imports vary strongly each year, so this trend cannot clearly be seen) (FAOSTAT, 2007).

4.2.2 Agriculture and Forestry Prices

Agriculture and forestry prices also represent an underlying driver of LUC. For example, the often lower market prices of palm oil compared to other vegetable oils (Figure 15) can explain why it is in high demand and its production is expanding (direct cause). Another reason is that the income that can be earned from producing palm oil is higher than from other food crops. Sunderlin and Resosudarmo (1996) suggest that smallholder net income would be twice as high on tree crop schemes as compared to food crop schemes once fully developed. Similarly, Chomitz et al. (2007 citing Tomich et al. 2005) find for Sumatra in 1997 that the net present value per hectare is 1 US$ for rubber agroforestry, 5 US$ for community forest management, while the net present value of oil palm cultivation amounts to 114 US$ and of unsustainable logging even to 1080 US$. This latter result also explains why illegal logging is so interesting from a financial point of view.

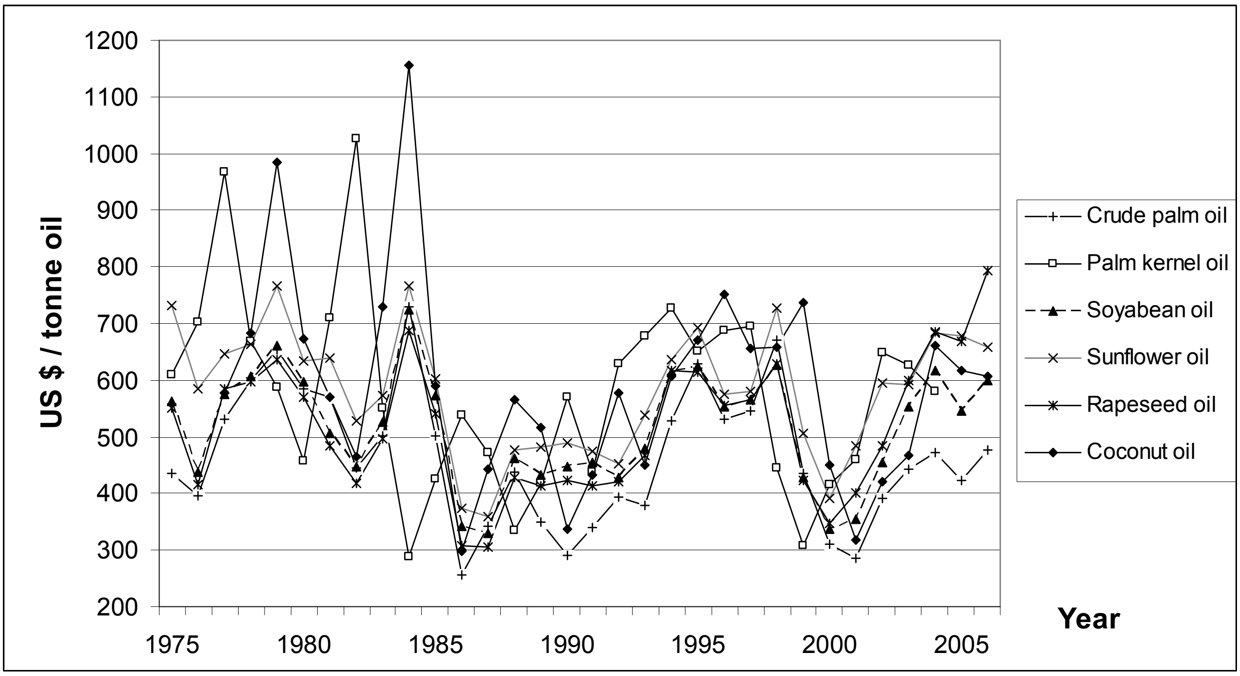


Figure 15: Average market prices of vegetable oils on the north-western European market
Source: MPOB, 2006 citing Oil World

4.2.3 Economic Growth

For Indonesia it was found that GDP per capita, as one indicator of economic growth, has constantly increased over the past thirty years (except during the Southeast Asian economic crisis in 1997 when GDP per capita in current US$ plunged to less than half the GDP per capita of the year before) (Figure 16). Economic growth is associated with increased demand for goods, which in turn spurs the demand for natural resources (section 4.2.4) and in particular for timber, for example, for construction - a direct cause of LUC. But, as will be seen in the next section, increased use of natural resources is also seen as a driver of economic development and growth.

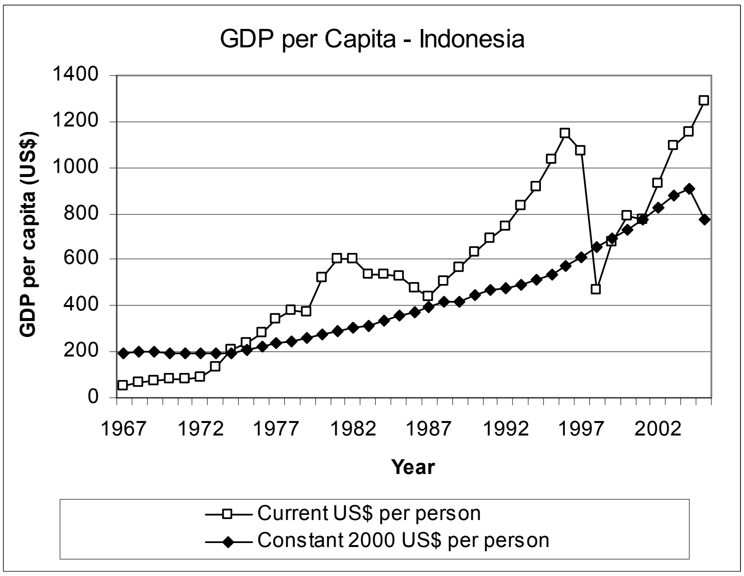


Figure 16: GDP per capita developments in Indonesia
Source: Earthtrends, 2007b citing World Bank - Development Data Group, 2007

Increased income generally goes hand in hand with an increasing and diversifying demand for food. This can be seen in, for example, increased dietary energy consumption per person from 2700 kcal/person/day in the early 1990's to 2880 kcal/person/day approximately ten years later (Table 17), and in the increased meat consumption, which changed from 3.5 kg per person in 1961 to 8.3 per person in 2002 (Earthtrends, 2007a). Additional food demand and especially higher meat demand results in more agricultural production (and/or increased imports), which together helps explaining why agricultural land area has been increasing in Indonesia.

Table 17: Dietary energy, protein and fat consumption in Indonesia over time

		1990-1992	1995-1997	2001-2003
Dietary energy consumption	kcal/person/day	2700	2890	2880
Dietary protein consumption	g/person/day	61	66	64
Dietary fat consumption	g/person/day	53	58	61

Source: FAOSTAT, 2008a

4.2.4 Policy and Institutional Factors

Various policy and institutional factors are underlying drivers of LUC in Indonesia. They include the orientation of policy to use natural resources to finance foreign debts (originally only timber from natural forest but no more and more also tree crops and timber from plantations), privatisation of timber and tree crop estates, corruption and land tenure conflicts caused by governmental allocation of concessions. In the following these factors are described.

Since the late 1960's and beginning 1970's Indonesian economic development policy was dominated by the idea of using natural resources to finance foreign debts and to economically develop Indonesia (Kartodihardjo and Supriono, 2000). One of the first changes in policy in which this phenomenon could be seen is the Basic Forestry Law from 1967, which declared all forest state property. This lead to "facilitating commercial access to and development of income streams from the legal rights to forest resources" (Siscawati, undated) so that foreign investment into logging activities became possible. As a result, Indonesia became one of the largest exporters of logs in the 1970's. In the mid 1980's, however, raw material shortages for timber processing plants in parts of Sumatra were observed due to overlogging (Siscawati, undated). Out of this shortage the government established the timber estates program - the promotion of timber plantations as a source for timber (Siscawati, undated). Then in 1990 the Indonesian Ministry of Forestry started granting concessions for industrial timber plantation on unproductive areas of permanent production forest so that forest land, which had been designated to remain production forest in the long term, could now be converted to timber plantations (Kartodihardjo and Supriono, 2000). However, as already mentioned above, this reform created the perverse incentive that, if a logging concession becomes unproductive due to overlogging, it can be converted to timber plantations or tree crop plantations. Thus, when land is degraded it becomes legally available for timber and tree crop plantations (Siscawati, undated).

Another policy dominated by using natural resources for development is the policy on export diversification. As oil and natural gas exports accounted for a large share in export revenues while reserves were dwindling, the government started promoting the diversification of exports by exporting more pulp and paper as well as tree crops such as palm oil and natural rubber (Siscawati, undated).

Two aspects in the development of timber and tree crops plantations are important to mention - smallholder schemes and the discrepancy in allocation of concessions and actual planting of these concessions with timber or tree crops. Each is explained in the following.

Smallholders of palm oil production represent a large fraction of palm oil producers in Indonesia; on 35% of all the land cultivated with oil palm they produce 30% of all the palm oil production in Indonesia (IPOC, 2005). Smallholders are individual farmers that plant palm oil on small land areas. They either decided to do so independently or were placed into nucleus-estate plantations, which are part of the transmigration schemes of the Indonesian government. In the latter case, the transmigrants were relocated from the crowded islands of, for example Java and Bali, to the outer islands and were given a small piece of land for cultivation of palm oil. In combination with smallholder palm oil production, large, private plantations with mills were developed which would buy the palm oil from the smallholders. These smallholder schemes are a part of the national policy on economic growth as small farmers are helped to make a living off palm oil while also increasing palm oil production, which in turn helps diverse exports.

The second aspect to consider in this section is the application of timber companies for concessions for converting forest to palm oil or timber plantations, then clearing the trees in order to meet the raw material requirements for the timber processing industry and leaving the land unplanted. This phenomenon has been observed by many studies (Casson, 2000; Forest Watch Indonesia and Global Forest Watch, 2002; Rautner et al., 2005, Chomitz et al., 2007, Kartodihardjo and Supriono, 2000) even though quantification of the actual problem has been difficult to impossible. Colchester et al. (2006) estimate that "in the past 25 years, no less than 18 Mha of forests have already been cleared for oil palm in Indonesia yet only about 6 Mha have actually been planted. The implication is that some 12 Mha of forests were cleared in the name of oil palm development by unscrupulous developers who only wanted access to the timber and never intended to plant oil palms at all" (Colchester et al., 2006). As similar situation is experienced with timber plantation concessions: Literature indicates that not all approved timber plantation concessions are actually converted to plantations: Kartodihardjo and Supriono (2000) show for 1997 that only 2 Mha out of 4.6 Mha that were approved in year 1997 for timber plantations were actually planted with trees. FWI/GFW (2002) states that in year 2000 only 1.9 Mha were planted with trees out of a total of 7.9 Mha approved for timber plantations. Thus, Kartodihardjo and Supriono suggest that "between 1990 and July 1997, the overall realisation of planting activity has only reached 24% of the total area planned" (Kartodihardjo and Supriono, 2000). By December 2004, 114 units of plantation companies controlled 5.8 Mha of land (approved timber plantations) but had planted only 3.25 Mha (Indonesian Ministry of Forestry, 2007).[17] By December 2005 this has changed to 5.73 Mha land approved and 3.4 Mha planted (Indonesian Ministry of Forestry, 2007).[18] Reasons for this discrepancy are clarified by FWI/GFW (Forest Watch Indonesia and Global Forest Watch, 2002) and presented in Box 1.

[17] Forest Statistics of Indonesia, 2004: Tables IV_1_3 and IV_1_4
[18] Forest Statistics of Indonesia, 2005: Tables IV_1_3 and IV_1_4

Kartodihardjo and Supriono (2000) point out another issue which may have caused the planting of allocated timber plantation concessions to slow down or even stop. This is that the price for timber from timber plantations is very low due to an oversupply of timber from natural forest, a large part of which is cut illegally (Kartodihardjo and Supriono, 2000). According to Kartodihardjo and Supriono, therefore, timber plantations are not regarded as financially feasible as an independent business, explaining why planting rates on allocated land are low.

Box 1: FWI/GFW explanations for discrepancies in approval and planting of timber plantations

"The fact that less than one quarter of lands allocated for HTI concessions by 2000 had actually been planted is a symptom of several interrelated structural problems with the HTI program. The 1990 Regulation clearly states that HTIs are to be granted only on nonproductive areas of permanent forest estate and may not be granted in areas already under a logging concession (HPH). In practice, however, HTI concessions have frequently been established on still-productive forest land. According to calculations based on plantation company feasibility studies, as of June 1998, 22 percent of land managed as HTIs had been productive natural forest prior to plantation establishment (Kartodihardjo and Supriono, 2000:4). Many HTI concessions involve the conversion of a much higher proportion of natural forest area. […]

The economic rationale for establishing HTIs in still-forested areas is clear. First, establishing plantations on truly degraded lands is more expensive because it often requires considerable investment in land preparation to rehabilitate soil fertility. Second, HTI concessions include the right to obtain Wood Utilization Permits (IPKs), essentially licenses to clear-cut and use remaining standing timber. When HTIs are established in areas with considerable standing timber, the IPK provision furnishes the company with a large supply of essentially free timber. This dynamic, combined with the large supply of timber available from illegal sources, considerably diminishes incentives for wood-processing companies to follow through with the planting and harvest of HTIs.

Less than one fifth of the approximately 2 million ha allocated for sawnwood HTI development has actually been planted. HTIs established for production of pulp have done slightly better, with just under one quarter of the nearly 5 million ha allocated for pulp production planted. (*See Table 3.6*.) But it is clear from the overall low percentage of HTI area planted – only 23.5 percent of the total area allocated for all types of HTI – that planting and harvesting plantation trees is not the major reason for HTI development. Rather, growth in HTI area is being encouraged by generous financial subsidies and rights to clear-cut standing timber. (*See Note 23*.)

In addition, many HPH concession holders find it economically advantageous to convert degraded areas of their concessions to HTIs. As a World Bank study noted in 1998, "logging operations can degrade a site with little risk of serious penalty, and in the process set themselves up to receive a license to convert the site so damaged into an HTI or tree crop estate."24 Forestry Ministry data published in 1998 reveal that more than 2.7 million ha of HPH concessions had been converted to HTI concessions. (*See Table 3.8*.)"

Source: FWI/GFW, 2002
Note: HTI – plantation concessions; HPH – logging concessions

4.3 Literature Overview of Causes and Drivers of Land Use Change

The various direct causes and underlying drivers presented in the previous sections have influenced LUC with various intensities. Data from this study showed that palm oil production expansion has certainly taken a role in LUC as the land required for palm oil production had to be taken from other land use categories. However, the quite large increase in land area under oil palm cultivation cannot explain the tremendous loss in forest cover alone. While timber plantations have also grown quickly, they are still quite small compared to palm oil and other agricultural crop production. Logging on the other hand has taken place on very large areas of forest and has been much larger than sustainable yields would allow. Besides these general conclusions regarding LUC, in this study it was not possible to quantify each cause's and driver's contribution to Indonesian LUC due to the lack of information on the spatial distribution and chronological order of the various changes.[19] As it is not possible to analyse the causes and drivers' contributions to LUC in this study, this section gives an overview of literature findings on this topic. Literature findings are categorized by the scale of analysis; data from 1) all of Asia, 2) all of Indonesia, 3) Sumatra and 4) Riau is presented.

Based on 55 case studies in all of Asia, Geist and Lambin (2002) found that the combination of the causes *agricultural expansion* and *wood extraction* (22% of all case studies included) dominates as the cause of deforestation while the combination of *agricultural expansion*, *wood extraction* and *infrastructure extension* was found to be a problem in 38% of the case studies included.

For Indonesia in the early 1990's, Sunderlin and Resosudarmo (1996) prepared an overview of literature from which they estimated the share of different causes in deforestation (Table 18). Table 18 shows that many of the studies see spontaneous transmigration together with traditional agriculture as the most important factor in deforestation and that also government transmigration has played a large role. But some studies have also put more emphasis on forest harvest and on fires as agents of deforestation. Sunderlin and Resosudarmo (1996) also clarify that in more recent years the trend of blaming mainly smallholders and traditional farmers for deforestation is shifting to blaming large-scale industry such as the palm oil sector and the logging companies. Dauvergne (1993) explains that previous estimates of the impact of swidden agriculture on deforestation have exaggerated the problem by assigning impacts to swidden agriculture when in fact they were a result of logging and development. Increased responsibility by the clearance for timber, pulp and paper industry and oil palm plantations for deforestation was also found by Forest Watch Indonesia and Global Forest Watch (2002). Hooijer et al. (2006) sees the same causes also for the loss of peatland forests in Indonesia.

Table 18: Estimation of annual deforestation in Indonesia

Source of Estimate	*Agent (%)*						
	Transmig. Dev't	**Estate Crops**	**Swamp Dev't**	**Spontan. Transmig**	**Trad'l Agri.**	**Forest Harvest**	**Fires**
World Bank 1990		28		55		9	8
FAO 1990	23	20	6.5	35		6	9
TAG 1991	25	4	12	60		NE	NE
MOF 1992	23	12	NE	23		6	36
Dick 1991	13	2	5	29	22	20	11

Source: Sunderlin and Resosudarmo, 1996

Notes: NE – no estimate; components may not sum up to 100% due to rounding

For Sumatra, Lewis and Tomich (2002) determine the key, distinguishable causes of deforestation between 1990 and 2002 as follows: timber estates account for 10%, tree crop estates (including palm oil) for 20%, pioneer farmers for 15%, small investors (of tree crops such as rubber, cocoa, coffee or cinnamon as opposed to palm oil) for 10% and forest fires for 4% of the total deforestation in Sumatra. According to Lewis and Tomich (2002) the causes for the remaining 45% of deforestation remain largely unexplained.

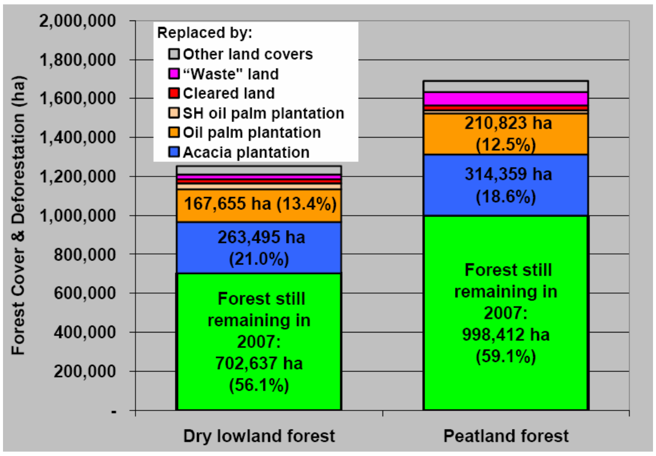
Land use change in Riau has primarily been caused by timber plantation and oil palm plantation establishment. See Box 2.

[19] While such information exists in the form of satellite images from various years, such an analysis of all of Indonesia was not possible within the scope of this study.

Box 2: Land use change in Riau, its drivers and its contribution on GHG emissions (based on Uryu et al., 2008)

Land use change in Riau

Between 1982 and 2007, Riau lost more than 4 Mha of forest. Forest cover declined from 78% (6.42 Mha) in 1982 to 27% (2.25 Mha) in 2007 (Uryu et al., 2008). While deforestation on Riau's peat soils amounted to 57% (1831193 ha) lost, the non-peat soils lost 73% (2335189 ha) of forest cover (Uryu et al., 2008). In recent years deforestation of non peat soils has been slowing, while deforestation of peat soil has been accelerating (Uryu et al., 2008).



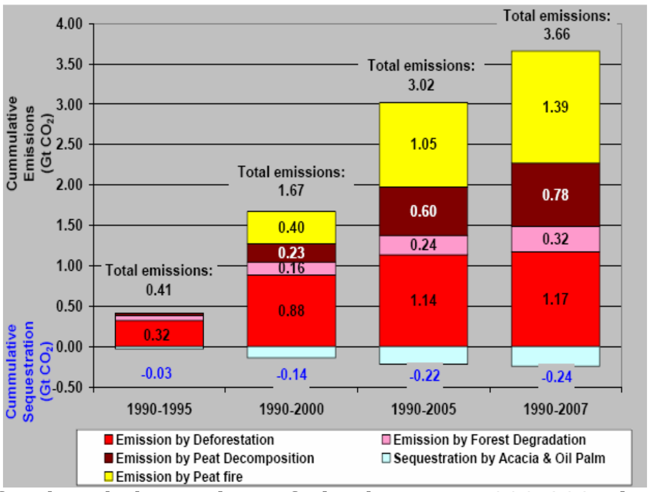
Replacement of 1990 dry and peatland forest by other land covers in 2001 (Uryu et al., 2008)

Drivers of LUC in Riau

"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). The remaining 30% of the cleared forest were replaced either by smallholder oil palm plantations (7%), appeared freshly cleared without an easily detectable future use in the analysis (5%) or were other land covers (18%) such as infrastructure, rubber, coconut and other plantations" (Uryu et al., 2008).

GHG emissions from LUC in Riau

GHG emissions from LUC (including fires) between 1990 and 2007 in Riau amounted on average to 0.22 Gt CO_2 per year (see figure below), which is 122% of the total annual emissions from the Netherlands in 2005 (Uryu et al., 2008).



Carbon budget for the whole province of Riau between 1990-2007 (Uryu et al., 2008)

5 PROJECTED FUTURE LAND USE IN INDONESIA

In this chapter, projections of future land use in Indonesia are made in order to determine the effect palm oil production expansion could have on future land use. Projections are made for palm oil and its land expansion based on various sources (section 5.1) and for reference land use such as forest and agriculture (section 5.2). The two projections are then combined to assess the feasibility and extent of oil palm expansion (section 5.3).

5.1 Palm Oil Production Expansion

Future palm oil production is projected on the basis of four different datasets: 1) extrapolation of past trends of land cultivated with oil palm, 2) FAO projections of palm oil production, 3) projections of the Indonesian Palm Oil Commission (IPOC) for land expansion and 4) expansion estimates found by Colchester et al. in their study "Promised Land" (Colchester et al., 2006). These projections are described briefly below and more details are presented in Appendix E and Appendix F.

1. **Past Trends**: A trend for the area under oil palm cultivation is determined for 2020 from historic developments of land area under oil palm cultivation (Indonesian Ministry of Agriculture, 2007): As regional data for 1997 and 2005 are available, these years are used to determine the average annual area expansion rate: 10% for Sumatra, 13% for Kalimantan, 14% for Papua, 5% for Sulawesi and 2% for the rest of Indonesia, giving a national growth rate of 10%. These growth rates are then used for determining the area under palm oil production in 2020 (including mature, damaged and immature). This extrapolation must be seen as an upper limit to expansion as very high expansion rates were observed in those years (see also Figure 7, which shows almost exponential growth in recent years).

2. **FAO**: The FAO projections for 2010 for oilseeds suggest a production increase of 5.9% per year for Indonesia (FAO, 2003). With given yields (depending on *base case* or *improved case*, see below), the mature palm area is determined. Projections for 2020 assume an annual production volume increase of also 5.9% after 2010. However, it is likely that production will slow down over time and that this percentage would be lower. But since no other information from FAO could be obtained, this percentage is used also for 2020.

3. **IPOC**: IPOC projects that in 2010 28 million tonne of palm oil will be produced (IPOC, 2007). This is will achieved by replanting 125 thousand hectare of existing plantations and expanding new plantations by 1.35 Mha. The projection of this study for 2020 assumes the same expansion rate for the period between 2010 and 2020 as the one projected for 2005 to 2010.

4. **Colchester**: In the study "Promised Land" from 2006, Colchester et al. determine the total area of expansion for palm oil in 2020 based on **provincial** expansion plans (Colchester et al., 2006).[20] This adds up to nearly 20 Mha of oil palm.

For each projections two cases are studied, which differ from each other by the yield applied and the share of immature and damaged palms in the total land area. The cases are *base case* and *improved case* and are described in more detail below.

[20] These provincial plans do not match the national plans (i.e. IPOC projections). The reasons for this discrepancy can be seen in that palm oil concessions are granted by the provinces' governors, who see palm oil production as a stimulant for economic development in their provinces.

Base case

Yields have increased from 3.1 t ha^{-1} y^{-1} on average between 1975 and 1979 to 3.6 t ha^{-1} y^{-1} on average between 1980 and 1989. But since then, the average yield has been 3.5 t ha^{-1} y^{-1} (Table 11). Therefore, for all cases except the IPOC projection, the yield is assumed to remain at 3.5 t ha^{-1} y^{-1}. As the IPOC study is the only study which actually presents yield estimations for the future, the IPOC projection here also applies the given yield of 4.1 t ha^{-1} y^{-1} (IPOC, 2007).

The *immature*[21] *and damaged*[22] area is also included in determining the land area. The "past trends" projection already includes immature and damaged area; IPOC and Colchester estimate the total area of expansion, which includes immature palms. For FAO projections, the immature area is determined by the share of immature palm oil area in 2005, which was 25% for Sumatra, 46% for Kalimantan, 24% for Papua, 19% for Sulawesi, 25% for the rest of Indonesia and 29% for Indonesia on average (IPOC, 2005).

Improved Case

The projections with improvements assume that the total production volume in 2020 remains constant compared to the *base case* projections but that yields are improved and that a 20% share of immature palms is applied. These measures are applied in order to see how much land will be required to obtain the same production level as in the *base case*. Assuming that production volume remains constant, the required mature area is determined with the improved yield. This land area is then used to calculate the area of immature palms by applying the percentage of immature palms in the total land area under palm oil cultivation (see below).

In the projections with an improved yield it is assumed that *yields* can increase to 5.85 t ha^{-1} y^{-1} in 2020 (Dros, 2003).[23] It is interesting to compare these yields to the visionary targets of the Malaysian Palm Oil Board (MPOB), who envision Malaysian yields to reach 5.6 t ha^{-1} y^{-1} in 2010 and 8.8 t ha^{-1} y^{-1} in 2020 (Jalani et al., 2002). Also Corley and Tinker (2003) confirm that oil yields are possible to be raised: the best yields obtained from breeding trials have exceeded 10 t ha^{-1} y^{-1}, while the theoretical potential yield is thought to be 18 t ha^{-1} y^{-1} (Corley and Tinker, 2003 citing Corley 1983 and 1998).

The high share of *immature* palms in Indonesia in 2005, which is primarily due to the large investments in new plantations in the recent past, may not be valid for the future. For Malaysia, where low replanting rates, and thereby a low share immature palms, have been one reason for lower yields than expected, Jalani et al. (2002) suggest that an appropriate share for the area of immature and young palms is 20%. Despite the contrasting situation in Indonesia, showing a very high share of immature palms, the Malaysian share of immature and young palms is also appropriate for Indonesia in the long term as with a slowing expansion the immature rate will automatically decrease if replanting does not occur. The age group "immature and young palms" includes palms with the age 1 to 7 years so that the share of immature only is likely to be even lower than 20%.[24] However, it is here assumed that immature and damaged palms account for 20% of all area under oil palm cultivation in Indonesia.

[21] Oil palms are generally considered immature until the age of three and produce no or very little fruit/oil (the closer they got to three) (Corley and Tinker, 2003).

[22] Damaged palms refer to damage caused by wind, flood, lightening and other environmental factors (see Appendix A). In 2005, the area of "damaged" palms amounted to approximately 1% for all types of producers (IPOC, 2005), which is why it is not considered further in the rest of this analysis.

[23] This increase in oil yields is based on an average annual increase in yields by 3%. This increase can be made possible by implementing better management practices, which help increasing the yield of fresh fruit bunches and the oil extraction rate (OER).

[24] Young palms (age 3 to 7 years) are already productive (even though lower yields than older, mature palms) and therefore, belong to the category "mature palms".

5.1.1 Results of Projections on Palm Oil Production Expansion

Results of the projections palm oil expansion by 2020 are presented in Table 19. In all projections very large increases in land area occupied by oil palm can be seen; the total land use by the palm oil sectors in 2020 ranges from 10.7 Mha in the IPOC projection to 25.4 million in the Colchester projection. Similar in size are the IPOC and the FAO projections, while the past trend projection is comparable to Colchester. When yields are increased and a share of 20% for immature palms is assumed, much smaller land areas are required to meet the same palm oil production volumes as in the previous projections (Table 19). Land area occupied by oil palm then ranges from 6 Mha in the FAO and IPOC projections to 12 Mha in the past trend projections and 13 Mha based on the Colchester estimations.

Table 19: Projections for land expansion by palm oil industry in 2020

		Past trends	**FAO**	**IPOC**	**Colchester**
BASE CASE					
Matura area	1000 ha	16317	8852	7622	17976
Immature area	1000 ha	6692	3630	3126	7372
Indonesia total 2020	**1000 ha**	**23009**	**12482**	**10749**	**25348**
Additional land requirements	**1000 ha**	**17501**	**6974**	**5240**	**19840**
Average annual expansion	1000 ha/y	1167	465	349	1323
Average annual growth rate[a]	%/y	10	6	5	11
IMPROVED CASE [b]					
Matura area	1000 ha	9372	5084	5083	10325
Immature area	1000 ha	2343	1271	1271	2581
Indonesia total 2020	**1000 ha**	**11715**	**6355**	**6354**	**12906**
Additional land requirements	**1000 ha**	**6207**	**847**	**845**	**7397**
Average annual expansion	1000 ha/y	414	57	57	493
Average annual growth rate[a]	%/y	5	1	1	6
Reduction from base case	%	49	49	41[c]	49
Share of yield improvement in reduction[d]	%	92	92	89	92

a – Reference in 2005 is 5508 thousand hectare used by palm oil production

b – The improved case refers to both improvements in yields and a share of immature palms of 20% as described in the text.

c – The reason for the reduction percentage of the IPOC projection to be lower than for the other projections is that the IPOC projections without yield improvements accounts for a higher yield than in the other projections (4.1 vs. 3.5 t ha^{-1} y^{-1}). This is because the IPOC study presents this yield as achievable in 2010 while in the other projections it is assumed that yields remain constant as they have over the last 10 years.

d – The share in yield improvement in reduction refers to the effect that only improving yields has on the reduction of additional land requirements.

The average annual expansion in the base case amounts to more than 1 Mha per year for the past trends and the Colchester projections, while it is 0.47 and 0.35 Mha for the FAO and IPOC projections. The average annual expansion is significantly reduced in the improved case, in which average annual expansion rates of 0.41 and 0.49 Mha per year for the past trends and the Colchester projections are required, while this is only 0.06 Mha for the FAO and IPOC projections. This compares to the past average annual expansion that amounted to 0.3 Mha between 1990 and 2005 per year and to even slightly more than 0.5 Mha per year between 1997 and 2000. Annual expansion is restricted by the limited amounts of required seeds, skilled labour, logistics, equipment and machinery but it is unclear what the maximum technically feasible area of average annual expansion is for Indonesia. Thus, despite high ambitions for expansion and an increasing demand for palm oil, it may not even be technically feasible to expand in such a manner as suggested by the study of Colchester or past trends projections.

With improvements, up to 50% of the land under oil palm cultivation can be avoided by (Table 19). Differentiating between the effects of yields versus a lower share of immature palms shows that most of the very large reduction potential comes from yield improvements rather than from a lower share of immature palms (Table 19).

The reason for the reduction percentage of the IPOC projection to be lower than for the other projections is that the IPOC projections in the base case account for a higher yield than in the other projections. This is because the IPOC study presents this yield as achievable in 2010 while in the other projections it is assumed that yields remain constant as they have over the last 10 years.

5.2 Reference Land Use

With the three projections for future reference land use (section 2.4) available land for palm oil production until 2020 is determined. Table 20 presents the categories in which land is freed and the amount of land. It can be seen that in the *Business as usual* reference land use system large forest cover loss occurs and that therefore, also a large amount of land becomes available (40 Mha). Due to not accounting for land from deforestation in the *Small Improvements* reference land use, available land decreases considerably to 15 Mha. Available land decreases further in the *Sustainability* reference land use system because now it is also assumed that agricultural land requirements will not be allowed to expand on forest land but rather on degraded land. As a result, available land for palm oil production decreases to a total of 8 Mha.

Table 20: Land availability in 2020 under different projections

	Reference land use projection		
	Business as usual	*Small improvements*	*Sustainability*
		1000 ha	
Deforested land [a]	21081	0	0
Conversion forest [b]	15705	11139	0
Agriculture	-6416	-6416	-2188
Timber plantations	-2405	-2405	-2405
Degraded land	12500	12500	12500
Total land available	**40464**	**14817**	**7907**

Note: A negative number refers to additional land required in this category, while a positive number refers to land made available in this category that can be used for oil palm production

[a] – including deforestation on conversion forest

[b] – excluding the part of conversion forest which is deforested

5.3 Land Balance

The land requirements under the different reference land use projections (Table 20) are matched with the required land for each oil palm expansion projection[25] in order to see whether enough land for the projected expansion is available. The results of this matching are presented in Table 21. In the table, positive numbers refer to land that is remaining after palm oil expansion, i.e. surplus land, and a negative number refers to a shortage in land for palm oil.

The main results of the matching of required land with available land (Table 21) can be summarised as follows:

- All oil palm projections can find enough land in 2020 *IF* deforestation continues as in the past and *IF* this deforested land becomes available for oil palm expansion (*Business as usual*). Thus, deforestation can provide the necessary land for oil palm expansion requirements. However, this development is not desirable from a sustainability point of view.
- With improvements in yields (from currently 3.5 to 5.5 tonne CPO per hectare and year in 2020) all projections greatly reduce land requirements, which in most cases can then be met by currently degraded land.
- The projections *Past trends* and *Colchester* require significantly larger amounts of land than could be made available in 2020 in the reference land use cases *Small Improvements* and *Sustainability*. However, with improvements in yields and an immature palm share of 20% both of these projections could be realised.
- Land requirements by FAO and IPOC projections can be met even without improvements in the *Sustainability* reference land use. However, with improvements much less land is needed and the available land for other uses such as deforestation is larger.

[25] Only the additional land that is required in 2020 is used here as it is assumed that land, which is now already in use for palm oil production, remains cultivated with oil palm.

Table 21: Land balance for Indonesia in 2020

Palm oil projections		Reference land use projection: *Business as usual*	*Small improvements* (1000 ha)	*Sustainability*
Past trends	base	22964	-2684	-9594
	improved[a]	34258	8610	1700
FAO	base	33490	7843	933
	improved	39617	13970	7060
IPOC	base	35224	9577	2666
	improved	39619	13972	7061
Colchester	base	20624	-5023	-11933
	improved	33067	7419	509

Note: positive numbers refer to land that is remaining after palm oil expansion (surplus land); a negative number refers to a shortage in land for palm oil expansion.
[a] – improved projection includes improved yields as well as a 20% share of immature palms

Table 22 shows how much of the expansion will be met by employing degraded land. The assumption that degraded land is not economically interesting until land from all other categories is used up is reflected in this percentage. In the estimated reference land use projection *Business as usual* no degraded land will be used while in the *Sustainability* projection 100% of the expansion is matched by degraded land in most cases. The only exceptions are the base case in the past trend extrapolation and the Colchester projection, which require more land than is available as degraded land.

Table 22: Percentage of expansion occurring on degraded land in 2020

Palm oil projections		Reference land use projection: *Business as usual*	*Small improvements* (%)	*Sustainability*
Past trends	base	0	71	71
	improved	0	63	100
FAO	base	0	67	100
	improved	0	0	100
IPOC	base	0	56	100
	improved	0	0	100
Colchester	base	0	63	63
	improved	0	69	100

From all the projections presented above, three extremes are chosen and their LUC are presented in Figure 17. The base case of the Colchester projection with the *Business as usual* reference land use (Figure 17 – bottom left) shows how the steep increase in palm oil expansion can be met by the decreasing forest. The base case of the IPOC projection with the *Small improvements* reference land use (Figure 17 – bottom right) demonstrates that under a projection with much lower land requirements for palm oil production and if deforestation continues as in the past, the category "rest" will increase, which may show that there will be more deforested and degraded land. The improved case of the Past trend projection combined with the *Sustainability* reference land use (Figure 17 – top) is used to demonstrate that palm oil land expansion is possible while forest cover remains constant compared to 2003 levels.

In the reference land use projection *Business-As-Usual* and *Small Improvements*, it was assumed that palm oil was produced also on peatland. As described in the Appendix B, this study assumes that in the future 27% of all palm oil plantation land will be located on peatland. From the total land area required for oil palm expansion the amount of peatland under oil palm cultivation is determined (Table 23). It can be seen that, depending on the specific projection, in the base case between 2.9 and 6.8 Mha of peatland will be used for palm oil production, while this is only 1.7 to 3.5 Mha in the case that improvements are applied. In reference land use projection *Sustainability* no peatland is allowed to be used.

Table 23: Additional peatland used by palm oil production in 2020

	Past trends	FAO	IPOC	Colchester
		1000 ha		
base case	6212	3370	2902	6844
improved case	3163	1716	1715	3485

Note: Data presented refers to the reference land use Business-As-Usual and Small Improvements. Use of peatland in the sustainability reference land use is not allowed because of the unsustainability of draining peatlands and converting them to crop production.

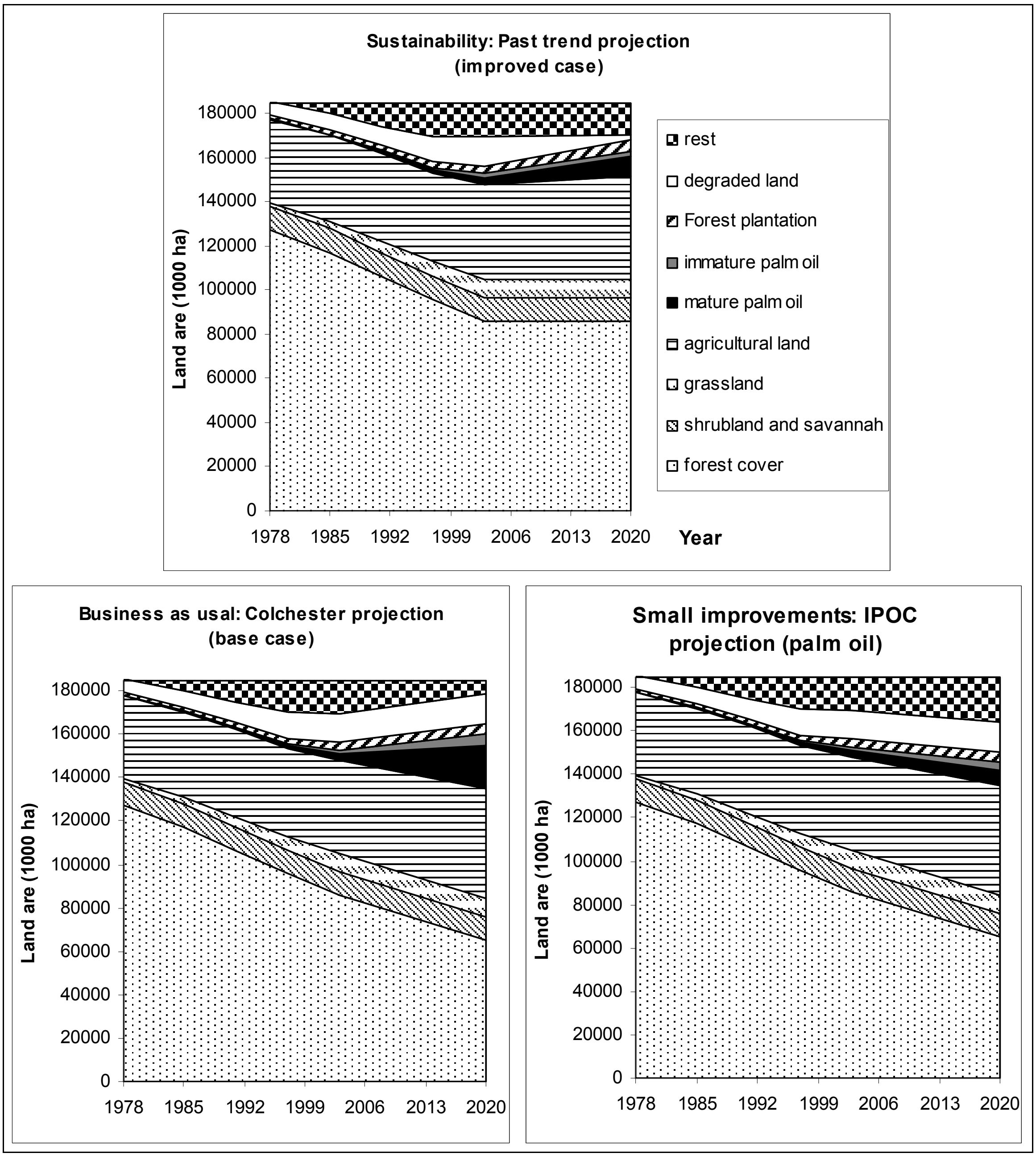


Figure 17: Land use changes under the three projections (selection)

Note: Each reference land use projection is presented for one case of palm oil expansion projection:
The *Business-As-Usual* reference land use is shown for the base case of the Colchester projection
The *Small Improvements* reference land use is shown for the base case of the IPOC projection
The *Sustainability* reference land use is shown for the improved case of the Past trends projection

Regional expansion of palm oil

The future expansion of palm oil in Indonesia has so far been determined for a national level. However, it is important to consider where in Indonesia this expansion will occur. Some literature sources suggest that expansion of oil palm is likely to primarily take place in western Indonesia such as Sumatra and Kalimantan as suitable soils, infrastructure, processing and markets are found there (Forest Watch Indonesia and Global Forest Watch, 2002). However, it is also suggested that land shortages in the west will lead to an increased expansion of oil palm mainly in East Kalimantan, Sulawesi and Papua (Wakker, 2000 and Forest Watch Indonesia and Global Forest Watch, 2002). However, mainly the lack of existing infrastructure but also of workers on the outer islands has kept recent investments in those areas limited and it is uncertain how these limitations will affect investments in the future.

The ISRIC – World Soil Information study about the suitability of palm oil expansion in Kalimantan (Mantel et al., 2007) found that nearly 0.9 Mha of land are of optimal biophysical suitability and 26 Mha of possible biophysical suitability. Optimal and possible suitability combined presents enough land to meet the land requirements of all the projections made in this study. However, Mantel et al. (2007) also find that if current use and land ownership of this suitable land is accounted for the land availability is greatly reduced. Potential expansion area then amounts to nearly 0.6 thousand ha (Mantel, 2008, personal communication).

The matching of available land with land requirements for palm oil expansion on a regional scale also needs to account for the spatial distribution of degraded land and its severity of degradation if this is where palm oil production should occur. Because only little is known about the exact location of degraded land and because there are also many other factors, which will influence the expansion of oil palm, such as the allocation and location of palm oil concessions, regional expansion was not determined in this study.

6 GREENHOUSE GAS EMISSIONS FROM LAND USE CHANGE IN INDONESIA

In sustainability discussions the greenhouse gas (GHG) balance of bioenergy is an important sustainability criterion. This is because the presumed GHG emission savings compared to fossil energy are a key driver for increasing bioenergy consumption in Europe and many other countries. However, it cannot simply be assumed that bioenergy results in GHG savings as the LUC associated with biomass and inputs to production such as fossil fuels for machinery, fertiliser and pesticides can all create GHG emissions (Reinhardt et al., 2007, Dornburg and Faaij, 2005, van Dam et al., 2004). Especially LUC has been found to largely influence the GHG balance (Reinhardt et al., 2007, Hooijer et al., 2006, Reijnders and Huijbregts, 2008). As explained in section 2.5, only the GHG emissions from LUC associated with palm oil production are studied. Emissions from the production of palm oil such as N_2O emissions from fertiliser application, CO_2 emissions from fossil diesel use or CH_4 emissions from the wastewater treatment are also not included as only emissions from LUC are studied (for further reference to GHG emissions from plantation and mills see Wicke et al., 2007).

The annual GHG emissions from only LUC as a result of palm oil production expansion in Indonesia are presented in Table 24. The results show only those emissions that are caused by future LUC as a result of palm oil production expansion as LUC is the focus of this study. Not included are emissions from current land use under oil palm cultivation as it is not known how much forested land, logged over forest, degraded land or peatland was converted to palm oil. It is assumed that these emissions are already accounted for in the total land use and forestry emissions in Indonesia 2005 with which the calculated emissions are compared (Table 25).

Table 24: Annual GHG emissions from LUC as a result of palm oil expansion until 2020

		Reference land use projection		
		Business as usual	*Small improvements*	*Sustainability*
Palm oil projection		million tonne CO_2-eq / year		
Past trends	base case	589	not possible[a]	not possible[a]
	improved case	187	24	-34
FAO	base case	210	20	-38
	improved case	26	37	-5
IPOC	base case	158	30	-28
	improved case	26	37	-5
Colchester	base case	599	not possible[a]	not possible[a]
	improved case	223	18	-40

[a] – This combination of reference land use projection and palm oil expansion projection is not possible due to lower land availability than land required for expansion (see Table 21)

In the *Business as usual* reference land use system very large emissions would be observed that would be equivalent to almost one fourth (23%) of the total land use and forestry emissions in Indonesia in 2005 (Table 25). This is mainly due to the use of natural rainforest and drained peatland for palm oil production. In the *Sustainability* reference land use on the other hand it is possible to generate negative emissions; that is, LUC associated with palm oil expansion absorbs more carbon than is emitted from land conversion due to increased above- and belowground biomass as well as higher soil carbon content on palm oil plantations compared to degraded land (Syahrinudin, 2005).

Interesting to note is that the emissions of the base case in the FAO and IPOC projections in combination with the *Small improvements* reference land use are lower than those of the improved case. This is due to the much larger land requirements in the base case, in which case degraded land must be used to meet all the land demand. This land type, however, has negative emissions and thereby reduces the total emissions of the base case compared to the improved case that uses no degraded land (Table 22).[26]

This result is problematic because it gives a positive connotation to large land requirements for palm oil production. However, it must be stressed that if land requirements are lower (as in the improved case) more degraded land could be used for reforestation and thereby obtain much larger carbon absorption than a palm oil plantation. Thus, a different allocation of these emissions or CO_2 absorption would adjust this outcome. It was chosen not to include this here as reforestation will have to be increased strongly from its current level, which in turn requires stronger involvement of the Indonesian government, and it is not certain whether this will actually happen.

Table 25: Comparing GHG emissions from LUC as a result of palm oil expansion with emissions from LUC in 2005 in Indonesia and with total emissions from the Netherlands in 2005

		Reference land use projection					
		Business as usual		*Small improvements*		*Sustainability*	
Palm oil projection		Indonesia LUC 2005	NL total 2005	Indonesia LUC 2005	NL total 2005	Indonesia LUC 2005	NL total 2005
		%					
Past trends	base case	23.0	274.5	n/a	n/a	n/a	n/a
	improved case	7.3	87.3	1.0	11.4	-1.3	-15.6
FAO	base case	8.2	98.1	0.8	9.4	-1.5	-17.6
	improved case	1.0	11.9	1.4	17.2	-0.2	-2.1
IPOC	base case	6.2	73.7	1.2	13.8	-1.1	-13.2
	improved case	1.0	11.9	1.4	17.2	-0.2	-2.1
Colchester	base case	23.4	279.1	n/a	n/a	n/a	n/a
	improved case	8.7	104.1	0.7	8.4	-1.6	-18.6

Note: Emissions from LUC in 2005 in Indonesia amount to 2563 million tonne CO_2-eq (Sari et al., 2007) and total emissions from the Netherlands in 2005 amount to 215 million tonne CO_2-eq (Brandes et al., 2007).

[26] As mentioned above, in the reference land use projections *Business-As-Usual* and *Small Improvements* it is assumed that degraded land is used only as a last resort. That means that degraded land is only used if all land of the other land types is used up.

MALAYSIA

7 LAND USE CHANGE IN MALAYSIA FROM 1975 to 2005

The Southeast Asian constitutional monarchy of Malaysia is administratively divided into 13 states of which 11 are located on the peninsular and two (Sabah and Sarawak) are located on the island of Borneo (Figure 18). Of Malaysia's total area of 33 Mha, 12.3 Mha belong to Peninsular Malaysia, 7.4 Mha to Sabah and 12.4 Mha to Sarawak.

In order to make an overview of LUC in Malaysia, the following sections describe each land use category and its developments over time. First, an overview of the available data is given for the following land categories: forest (section 7.1), agriculture (section 7.2), palm oil (section 7.3), peatland (section 7.4), shrubland, savannah and grassland (section 7.5), degraded land (section 7.6), and burnt and barren land (section 7.7) and then, based on the individual land use changes, an overview of past LUC in Malaysia is presented and knowledge gaps and uncertainties discussed (section 7.8).

Figure 18: Map of Malaysia

7.1 *Forest*

As for Indonesia (section 3.1), the section of the extent of forest and its developments over time is subdivided into two parts: First, data on forest land is presented and compared. Then data on forest cover and its change over time is presented to show the discrepancies between forest land and forest cover in Malaysia (see section 3.1 and Appendix A for definitions of forest land and forest cover).

7.1.1 Forest Land

Forest land in Malaysia is referred to as permanent forest estate (PFE), the total area of forest land that has been legally designated for retention as forest in the long term (see Appendix A for more details of the definitions). Besides PFE there are two other forest land categories. These are 1) state land forest, which is land owned and managed by the state and earmarked for future conversion to other uses than forest, and 2) national parks, wildlife sanctuaries and wildlife reserves, which are totally protected areas demarcated under the

Wildlife Act 1972 (Kumari, 1995) (Table 26). Data on land areas occupied by PFE, state land forest and national and wildlife parks were found for 1991, 1997 and 2006 in various sources and for 1990, 2000 and 2005 in FAO Global Forest Resource Assessment 2005 (FRA 2005) (FAO, 2006a) and presented in Table 26. The 1991, 1997 and 2006 data on PFE is also divided into protective PFE, "aimed at sound climatic and physical condition of the country, soil fertility and environmental quality, and minimization of damage by floods and erosion to rivers and agricultural land" and productive PFE, "intended to ensure supply in perpetuity of forest produce, principally timber for domestic purposes and export earning" (Sothi Rachagan, 1998). This breakdown could not be made for 1990, 2000 and 2005 due to lack of data.

Table 26: Malaysia's permanent forest estate, national and wildlife parks, and state land forest over time

	1991	1997	2006	1990	2000	2005
		1000 ha			1000 ha	
Protective	2830	3430	3210	-	-	-
Productive	11230	10850	11180	-	-	-
Total PFE	**14060**	**14280**	**14390**	**12600**	**14400**	**14400**
National and wildlife parks	1600	2120	1800	1120	1120	1120
State land forest	3600	2510	3300	6820	4640	4141
Total	**19260**	**18910**	**19490**	**20540**	**20160**	**19661**

Source: **1991:** Earth Observation Centre, 1999
1997: Sothi Rachagan, 1998
2006: Basiron, 2007
1990, 2000, 2005: FAO, 2006a

When looking at the first dataset (1991, 1997 and 2006), it can be seen that the land areas of PFE, national and wildlife parks and state land forests have all been fluctuating. Generally, 1997 data was lower than 1991 and 2006, and 2006 data is higher than 1991 (Table 26). The protective PFE is an exception, amounting to 2.8 Mha in 1991, then increasing to 3.4 Mha by 1997 and decreasing again to 3.2 Mha in 2006. It is unclear whether the differences in data are caused by using three different datasets or whether actual changes in forest land area occurred.

The FAO FRA 2005 data gives a slightly different picture: total forest land decreases by 0.9 Mha from 1990 to 2005. The loss is primarily caused by a loss in state land forest. Even though PFE area increases, this cannot negate the loss of state land forest. It would be interesting to know the breakdown of PFE in protective and productive PFE in order to determine whether both categories increased or only one of them. However, the FAO FRA 2005 does not present this information.

More than half of the total forest land is comprised of productive PFE, amounting to 11.2 Mha in 1997, and decreasing slightly to 11.1 Mha by 2006. In this area logging and foraging for rattan, medicine and wild plants is allowed to occur (Sothi Rachagan, 1998). Therefore, not all of the 11 Mha of productive forest may be considered as land with forest cover. In addition, state land forest is generally included in Malaysian forest data even though it may be subject to logging concessions and conversion to other uses and, therefore, to possible forest degradation (Sothi Rachagan, 1998). Therefore, it is important to look at forest cover data also (see the following section on forest cover). But first, an overview of regional forest land is given.

Regional Forest Land

Forest land as presented in Table 26 can also be distinguished for the three regions for the years 1991 and 1997 (Table 27).[27] Both Peninsular and Sarawak show a decrease in total forest land between 1991 and 1997, which comes both from a decrease in productive PFE and state land forest. Sabah shows an increase in total forest land, which is caused by an increase in PFE, mainly in protective PFE, while national and wildlife parks decrease slightly and state land forest decrease by 300 000 hectare as well.

[27] Data from 2006 is not broken down per region.

Table 27: Regional forest land

	Peninsular		Sarawak		Sabah		
	1991	**1997**	**1991**	**1997**	**1986**	**1991**	**1997**
	1000 ha						
Protective	1900	1900	580	530	-	350	1000
Productive	2810	2780	5420	5000	-	3000	3070
Total PFE	**4710**	**4680**	**6000**	**5530**	**3330**	**3350**	**4070**
National and wildlife parks	740	740	470	1000	252	390	380
State land forest	670	430	2230	1610	888	700	470
Total	**6120**	**5850**	**8700**	**8140**	**4470**	**4440**	**4920**

Source: **1986 Sabah:** Marsh and Greer, 1992
1991: Earth Observation Centre, 1999
1997: Sothi Rachagan, 1998

It is interesting to note that the government of Malaysia only provides advice and technical assistance with respect to land and forest use to the states while the decisions are made by the states themselves. In practice the 11 states of the Peninsular Malaysia have adopted a common set of laws and regulations for forest management, while the states of Sabah and Sarawak have retained a higher degree of autonomy (MTC et al., 2007). The national government recommended in the National Forestry Policy 1977 and 1984 that each state sets aside 47% of its land area as PFE (McMorrow and Talip, 2001), which would amount to 5.8 Mha for all the peninsular states together, 5.8 Mha for Sarawak and 3.5 Mha for Sabah. As Table 27 shows the peninsular states together did not reach this recommendation in 1991 nor in 1997, while Sarawak reached it in 1991 but not in 1997 and Sabah did not reach it in 1986 and 1991 but in 1997.

Data on regional forest area over time is given by the Malaysia Economic Planning Unit (EPU) (Figure 19) and shows how forest area has decreased in the last 50 years. Because the definition on forest area applied by the EPU could not be obtained, it could not be verified whether the data actually refers to forest area or to forest cover. The reason for considering that this data refers to forest cover is that designated forest land has changed less over time than the forest area presented here.

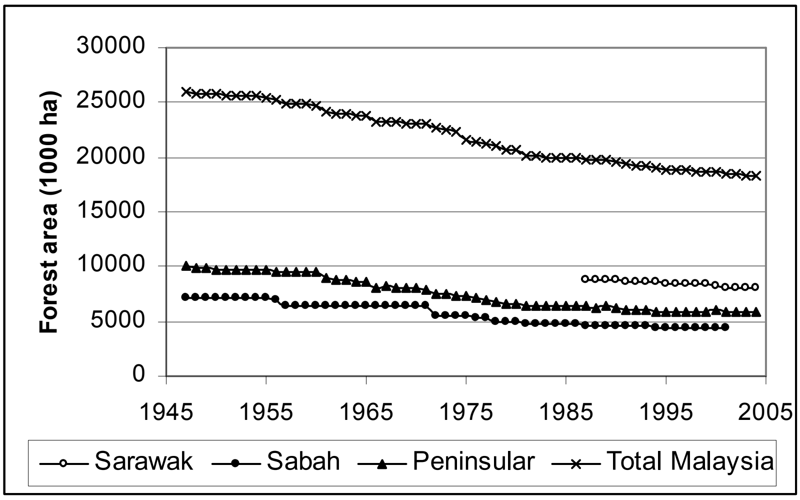


Figure 19: Forest area in Malaysia 1947- 2005
Source: Economic Planning Unit, 2008
Note: Data on Sarawak was only available for 1987 onwards. Therefore, the forest area of total Malaysia for 1947 to 1987 applies a constant value for Sarawak, namely the value in 1987. It is likely that forest cover was much higher in the beginning then presented by this assumption. In this case, forest area loss would decrease more rapidly in the period from 1947 to 1987.

7.1.2 Forest cover

Forest cover data is presented by various sources. The sources studied here are FAO FRA 2005 (FAO, 2006a), FAO FRA 2000 (FAO, 2001a), Stibig and Malingreau (2003), UNEP

(1997), FAO Forestry Department (2002) and the GLCC database (Earthtrends, 2007c). Data from each source is described in detail in Appendix G and an overview of the data is presented in Table 28. Comparing the various data sources indicates that there is a lot of uncertainty in forest cover data for Malaysia. For example, forest cover according to FRA 2005 is larger than the governmentally assigned forest land (as presented in Table 26). An analysis of the Malaysia country report for the FAO FRA 2005 (Kiam, 2005) reveals that FRA 2005 data on Malaysia is based on the legally assigned forest land PFE, state land forest and national and wildlife reserves. As mentioned above, especially productive PFE and state land forest are subject to logging and foraging of other forest products, which can cause degradation of forest, including forest cover loss and is the reason for why forest cover should be a distinct category from forest land. Moreover, the Malaysia country report for the FRA 2005 reveals that forest cover includes rubber plantations, which is equivalent to the different between forest data from FRA 2005 and the forest assigned by the Malaysian government.[28] While the inclusion of rubber plantations is made according to the FRA 2005 definition of forest (Appendix A) it deflects from natural forest cover. Both explanations can partially explain why Malaysian forest cover data from FRA 2005 is higher than the results of Stibig and Malingreau's (2003) analysis of satellite images. But it is interesting that FRA 2005 data is also quite different from FRA 2000 (despite similar definitions; Appendix A)[29] and FAO Forestry Department (2002) data. UNEP and GLCCD data are both uncertain (Appendix G) and are therefore not further included in the analysis.

Deforestation

According to FRA data (excluding rubber plantations), Malaysia forest cover declined on average 0.2 % per year in the period of 1990 to 2000 and 0.5% per year between 2000 and 2005 (Table 28) (FAO, 2006a). In absolute terms, on average almost 60 000 hectare were lost each year in the period from 1990 to 2005. Using the Stibig and Malingreau data for 2000 and FRA 2005 data for 1990, the deforestation rate between 1990 and 2000 results in 1.9%/y, which in absolute terms is 399 ha/y (Table 28). FRA 2000 deforestation is likely to be an overestimate of deforestation rates because the calculation includes rubber plantations, which have strongly decreased between 1990 and 2000 (see section 7.2).

Table 28: Overview of forest and other wooded land over time

		FRA 2005 (FAO, 2006a)			**Stibig and Malingreau 2003**	**FRA 2000** (FAO, 2001a)		**FAO Forestry Department 2002**
		1990	**2000**	**2005**	**2000**	**1990**	**2000**	**2001**
Total Malaysia	1000 ha	22376	21591	20890	18382	21661	19292	19800
Forest cover	%	68	65	63	56	66	58	60
Deforestation rate	1000 ha/y		-38 [a]	-100 [a]	399		237	169
Deforestation rate	%/y		-0.2 [a]	-0.5 [a]	-1.9		-1.2	-0.8

Note: The average deforestation rate of Stibig and Malingreau is determined for 1990 to 2000 with 1990 values taken from FRA 2005. Similarly, the FAO Forestry Department deforestation rate is also based on the 1990 value taken from FRA 2005.

a – Deforestation rates of FRA 2005 are determined without rubber plantations. The same could not be done for FRA 2000 data even though rubber plantations are also included. The area of rubber plantations could not be subtracted because the exact amounts are not known. While data on natural rubber plantations are available from FAOSTAT (see section 7.2), those only account for the harvested area and not the total area.

Forest Degradation

Data on forest degradation is difficult to obtain, partially because of different definitions applied. Here it is assumed that forest degradation refers to "changes within the forest which negatively affect the structure or function of the stand or site, and thereby lower the capacity to supply production and/or services" (FAO, 2001a). Here also the indicators of forest degradation, the area of logged-over forest and of disturbed forest, are used. The most detailed information was provided by the FAO study on Tropical Forest Resources Assessment Projection from 1984, in which 1980 logged-over forest areas[30] are given as 3.6 Mha in Peninsular, 1.3 Mha in Sabah and 0.7 Mha in Sarawak. Logged-over forest estimates

[28] Subtracting the area of rubber plantation from the total forest cover area results in the forest land data for 1990, 2000 and 2005 presented in Table 26. Data on developments in timber plantations are presented in section 7.1.3.
[29] According to the forest definitions both studies included rubber plantations.
[30] Logged over forest is defined in this study as "land area that was logged over once or more times during the last 60 to 80 years" (FAO, 1984).

are made for 1985: 3.6 Mha in Peninsular, 1.4 Mha in Sabah and 0.7 Mha in Sarawak – showing a 0.5% annual increase in logged-over forest areas in Malaysia.
Another source (ABC and WCMC, 1997) suggests that there were 1.37 Mha of degraded forest. It is unclear what definitions are applied here.

Some additional information is available for Peninsular Malaysia. Disturbance of forests in Peninsular Malaysia is depicted by Brookfield et al. (1995) in Figure 20. Additionally, from the Third and Fourth National Forestry Inventory for Peninsular Malaysia (1991-1993 and 2001-2003, respectively) also the area that is/was logged is documented (Kiam, 2005): according to the third inventory, the area logged before 1960 amounted to 0.37 Mha, between 1961 and 1970 this remained constant, 1971 to 1980 saw an increase to 0.9 Mha. The fourth inventory states the following: area logged before 1971 amounted to 0.6 Mha, between 1971 to 1980 this was 0.7 Mha, from 1981 to 1990 this was 0.9 Mha and between 1991 and 2003 the area logged amounted to 0.5 Mha. In the fourth inventory, the area of peat swamp forest that is/was[31] logged is given as 0.12 Mha. In addition, there were another 0.16 Mha of state land peat swamp forests that is/was logged and 0.5 Mha of stateland dipterocarp forests being logged. The data is unclear on whether there are overlapping areas in the different time period or if these are additional. Moreover, it is unclear why this data differs from the data presented by FAO (1984).

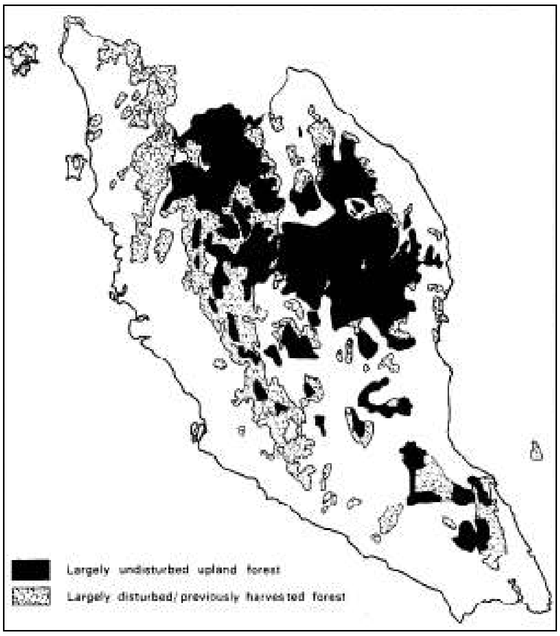


Figure 20: Remaining undisturbed forest and disturbed forest in Peninsular Malaysia in 1983
Source: Brookfield et al., 1995
Note: undisturbed forest marked black, disturbed forest marked grey/shaded

The changing size of primary forest in Sabah is an indicator of forest degradation: Since 1975 the area of primary forest fell from 2.8 Mha to 0.3 Mha in 1995, a depletion rate of 125 000 ha per year (McMorrow and Talip, 2001). The amount of logged over forest in Sabah in 1980 is estimated at 1.28 Mha (McMorrow and Talip, 2001), while this increased to 1.6 Mha in 1990 (Marsh and Greer, 1992). McMorrow and Talip (2001) present another indicator of forest degradation in Sabah: the area of disturbed forests. In 1975 this amounted to 1.4 Mha, while it doubled to amount to 2.8 Mha in 1995.

Only little information on forest degradation in Sarawak could be found. While Sarawak Forestry Department statistics show a decline in the total forest area by just over 10 % between 1980 and 1990, the official statistics conceal the fact that 8.8 Mha of forest had been licensed for logging by 1990 (JOGANGOHutan, 2006), which, depending on which data it is compared to represents nearly all of Sarawak’s forests.

[31] No information is given whether this land is still under logging concessions.

Regional Forest Cover

As for national statistics on forest land it is also true for the regional data on forest land that the area of forest land may not be representative of actual forest cover, considering that in both productive PFE and state land forest logging and foraging for other forest products is taking place. Both activities have proven to play a role in forest degradation and deforestation/forest cover loss. Therefore, regional data on forest cover was collected (Table 60 in Appendix G). It can be seen that forest cover on Peninsular Malaysia has continuously decreased to just half (in 2005) of the first obtained record from 1957 (Figure 21). Also in Sabah forest cover loss could be observed, however, less dramatically. Since 1953 forest cover decreased from 6.3 Mha to between 4.1 and 4.4 Mha in the beginning of the new millennium. Three different data sources for the years 2001, 2003 and 2005 show different amounts of forest cover in Sabah and it is unclear what the reasons for these varying results are. For Sarawak the data becomes even more uncertain. In 1966 Sarawak was found to have 8.5 Mha of forest cover, while in 2001 this was supposedly 9.8 Mha, in 2003 8.1 and in 2005 9.2 Mha. While all sources state they are referring to forest cover it is possible that this is not always the case. Because the data is much higher than from other sources, the 2001 data (FAO Forestry Department, 2002) and 2003 data (MTC et al., 2007) may possibly represent forest land instead of forest cover. Because no definitions of the used terms were obtained, this issue could not be resolved.

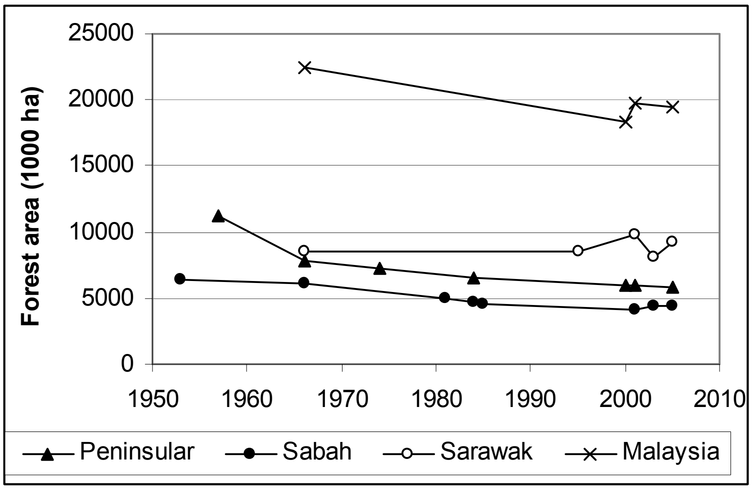


Figure 21: Forest cover loss in Peninsular Malaysia, Sabah and Sarawak over time

Note: The figures are based on Table 60 in Appendix G, where also the sources of data for the different years are given.

7.1.3 Timber plantations

The FAO Global Forest Resources Assessment 2005 (FRA 2005) also presents data on the area of timber plantations in Malaysia in 1990, 2000 and 2005 (Table 29). The data shows that timber plantations have been decreasing since 1990, when they amounted to nearly 2 Mha (Table 29). This decreased to 1.5 Mha in 2005, an annual decrease of 1.6% between 1990 and 2000 and a slightly slower decrease of 1.1% per year from 2000 to 2005 (Table 29). The largest part of the timber plantations is natural rubber plantations with around 80% of all timber plantations. There are two datasets on rubber plantations in Malaysia (Table 29). The first dataset is based on the country report of Malaysia for the FRA 2005 (Kiam, 2005), while the second is based on FAO STAT data on the harvest area of natural rubber (FAOSTAT, 2008b). It is likely that the difference in the two datasets is that FRA 2005 looks at total area while FAO STAT refers to harvested area only.

Natural rubber is included in the timber plantation area because it has been increasingly used for timber purposes and less for latex production. The reason for the changing use of rubber tress is better economic returns from selling timber rather than natural rubber (FAO, 2002a). In addition to other uses of the rubber tree, rubber tree plantations are also increasingly replaced by economically more favourable oil palm plantations. Because FAO STAT data for agricultural land also includes natural rubber plantations, the overview of the past LUC change is made (section 7.8) with the rubber plantations being shown in the category of agricultural land in order to avoid double counting.

Table 29: Developments in timber plantations in Malaysia

		1990	2000	2005	FRA 2000
- rubber plantations	1000 ha	1836 (1614)	1431 (1300)	1229 (1237)	1478
- other timber plantations	1000 ha	120	228	258	272
Total timber plantation	**1000 ha**	**1956**	**1659**	**1573**	**1750**
Annual average change	%/y		-1.6	-1.1	-
Annual average change	ha/y		-297	-172	-

Source: **Rubber plantations**: FAO FRA country report for FRA 2005: Kiam, 2005 (in parenthesis harvested area of natural rubber according to data from FAOSTAT, 2008b)
Other timber plantations: own calculations based on subtracting the area of rubber plantations from the total timber plantations
Total timber plantations: FAO, 2006a
FRA 2000: FAO, 2001a

The other timber plantations amount to 120 thousand ha in 1990 based on FRA 2005 rubber statistics, 228 thousand ha in 2000 and 258 thousand ha in 2005 (Table 29) and the most important tree species planted in Malaysia are *Acacia Mangium*, *Gmelina* and *Eucalyptus* (FAO, 2002b). Data on other timber plantation was also found in various other sources and is presented in Table 30. The values presented there are higher than the area of other timber plantations as determined with FRA 2005 data.

Table 30: Regional distribution of other timber plantations in Malaysia

		1980	1990's	2000	2001	2006
Peninsular	1000 ha	7.1	77.4	-	70	-
Sabah	1000 ha	18.8	89.8	-	150	206
Sarawak	1000 ha	Trial stage only	12.9	23.1	30	-
Total timber plantation	**1000 ha**	**25.9**	**180.1**	**-**	**250**	**-**

Source: **1980:** FAO, 1984
1990: FAO, 2002a
2000: Forestry Department of Sarawak, 2008
2001: FAO Forestry Department, 2002
2006: Sabah Forestry Department, 2008a

7.2 Agriculture

Since 1960 agricultural land use in Malaysia has almost doubled from 4.2 Mha to 7.9 Mha. The largest share of agricultural land was made up of permanent crops in 1960 and continues to do so today (Table 31). Also arable land has seen an increase in land area being used, namely from 0.8 to 1.8 Mha. While permanent pastures have increased as well, this change was minor compared to the changes observed for arable land and permanent crops (Table 31).

Table 31: Historic overview of agricultural land use in Malaysia

		1960	1970	1980	1990	2000	2005
Arable land	1000 ha	830	920	1000	1700	1820	1800
Permanent crops [a]	1000 ha	3150	3510	3800	5248	5785	5785
Permanent pastures	1000 ha	220	239	259	276	285	285
Agricultural land	1000 ha	**4200**	**4669**	**5059**	**7224**	**7890**	**7870**
Annual average change	%/y		1.1	0.8	3.6	0.9	-0.1

Sources: FAOSTAT, 2008c
a - Includes palm oil, which is treated in more detail separately in section 7.3.

The breakdown by crop (Table 32) shows that oil palm is the largest crop, with a land area of mature palm of 3.6 Mha and growing. It is important to note that the specific crop data is based on FAO STAT data on harvested area only. That means that for example, the land area of immature oil palm – an area not yet harvested – is not included. This implies that the area under oil palm cultivation is even larger than presented by FAO STAT data. Table 32 also indicates that two, once important crops in Malaysia, coconut and natural rubber, have slowly declined and made space for palm oil expansion. However, this trend may not continue in the future as currently high prices for all natural resources and agricultural products may slow down conversion to palm oil production.

Table 32: Breakdown of Malaysia's agricultural land

	1975	1990	2005
		1000 ha	
Arable land	**968**	**1700**	**1800**
- rice paddies	750	681	676
- oilseeds (only temporary)	35	80	120
- rest [b,c]	183	939	1004
Permanent cropland	**3710**	**5248**	**5785**
- oil palm	386	1746	3620
- coconuts	337	316	179
- coffee	16	13	53
- cocoa beans	17	298	33
- natural rubber	1700	1614	1237
- rest [b]	1270	1274	715
Permanent pastures	**268** [a]	**276**	**285**
Total agricultural area	**4946**	**7224**	**7870**
Annual average change of total agricultural area	**2.6**	**0.6**	

Source: FAOSTAT, 2008b (crops); FAOSTAT, 2008c (arable land, permanent cropland and permanent pastures)

a – Value refers to the first year available in FAO STAT for permanent pastures (1985)

b – Rest category is determined by subtracting the area of other, individual crops from the total arable land or permanent cropland, respectively.

c – It is unclear what other temporary crop(s) has (have) caused this large increase in the rest temporary crops category. The area harvested statistics from FAO STAT, from which the breakdown by crop is taken, present data for cabbages, cassava, cucumber, ginger, grapefruit, maize, pumpkins, paddy rice, roots and tubers, soybeans, sugar cane, sweet potatoes, tobacco, tomatoes, other vegetables and watermelons (besides paddy rice and oilseeds, which are shown in the table). All together, the area harvested of temporary crops listed by FAO STAT make up 930 000 ha, while the total arable land in the same year, as given by FAO STAT (Resources), amounts to 1 800 000 ha. The reasons for this discrepancy are unclear: The definition of arable land explains that also fallow land (less than five years) and temporary meadows for mowing and pastures are included, which are not included in the area harvested statistics of FAO STAT. However, it is unlikely that the addition of these two categories can explain this large discrepancy between arable land and the area harvested of temporary crops. Another partial explanation of the discrepancy may be found in the lack of data for certain crops in Malaysia.

7.3 Palm oil

Malaysia's palm oil plantation area has grown from 0.6 Mha in 1975 to 4.2 Mha in 2006 (Figure 22) (MPOB, 2006). Most of this expansion has taken place in Peninsular Malaysia but especially in the last decade the expansion took place in Sabah and increasingly in Sarawak (Figure 22). The main reason for a shifting expansion to the two eastern states is land scarcity and low suitability for palm oil production of the remaining land on the peninsular.

Table 33 shows an overview of the land area under oil palm cultivation in 2006 broken down by producer type and by maturity level. It can be seen that more than half of the land is owned by private estates, followed by government and state schemes combined with nearly 30% and smallholders owning 11%. Interesting to note is also the low share of immature palms in 2006 compared to the share of immature palms in Indonesia (30% in 2005): only 11% of all land under oil palm cultivation was immature (Table 33).

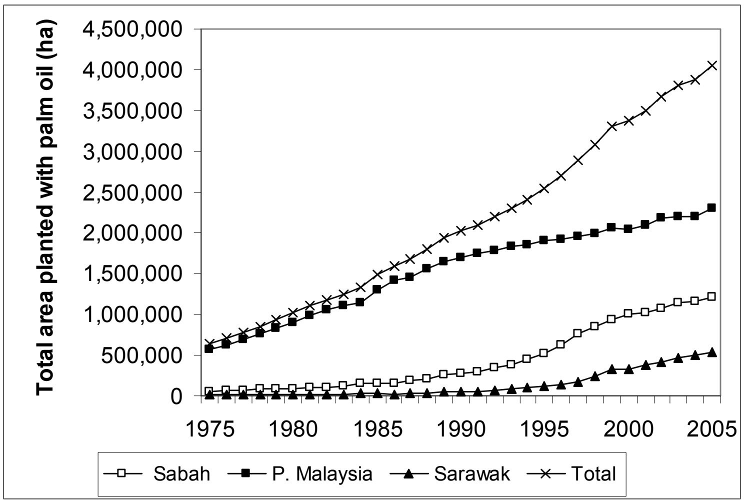


Figure 22: Total area planted with palm oil (mature and immature) in Malaysia, by region
Source: MPOB, 2006

Table 33: Land area under oil palm cultivation in 2006: breakdown by producer type and regions

	Smallholder	Private estates	Government and state schemes	Total	Percentage of total land
		1000 hectares (%)			%
Peninsular	**337** (14)	**1093** (47)	**905** (39)	**2335**	**19**
- mature				2093	17
- immature				242	2
Sabah	**95** (8)	**919** (74)	**225** (18)	**1239**	**17**
- mature				1139	15
- immature				100	2
Sarawak	**23** (4)	**465** (79)	**103** (17)	**591**	**5**
- mature				471	4
- immature				120	1
Total	**455** (11)	**2476** (59)	**1233** (30)	**4165**	**13**
- mature				3703	11
- immature				462	2

Source: MPOB, 2006

Yields of fresh fruit bunches, crude palm oil and palm kernels are presented in Table 34 and show that yields were highest in Sabah, which is likely due to the high suitability of the soils there. Yields are lowest in Sarawak, which may be due to the more recent developments there as a result of which still a higher percentage of palms is immature than in the rest of the country. But it is likely to be due to less suitable soils (often peat soils) in Sarawak. Figure 23 presents the development of CPO yields over time, showing that yields in Sabah have been increasing even further while yields in Peninsular Malaysia have decreased over the 15 year period shown.

Table 34: Production yields in 2005: FFB, CPO and palm kernel

	Fresh fruit bunches	Crude Palm oil	Palm kernel
		tonne/ha	
Peninsular	18.7	3.6	1.0
Sabah	23.1	4.9	1.1
Sarawak	15.5	3.3	0.7
Total Malaysia	**19.6**	**3.9**	**1.0**

Source: MPOB, 2006

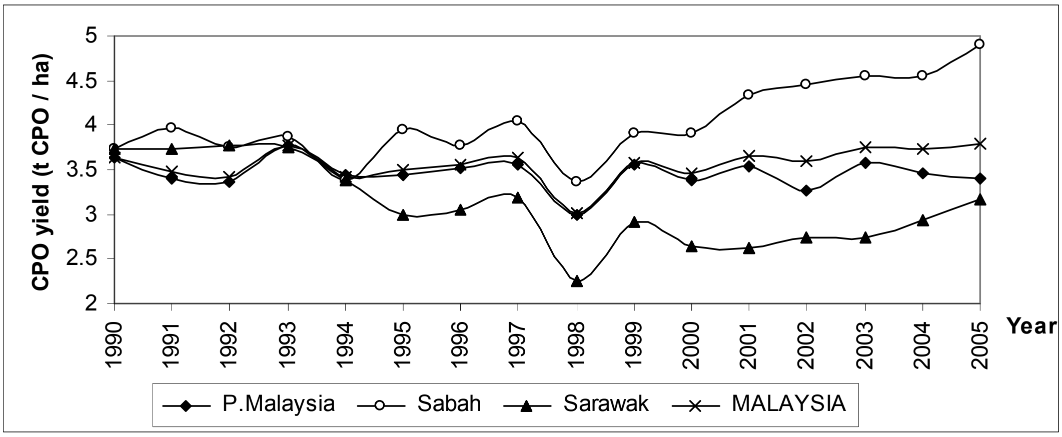


Figure 23: CPO yield developments in Malaysia, by region

7.4 Peatland

Rieley and Page (2005) estimate that the total peatland area in Malaysia is 2.7 Mha while Hooijer et al. (2006) determine only 2 Mha of peatland in Malaysia (Table 35). The forest cover of peatland has decreased rapidly in the past, from approximately 2 Mha in the beginning of the 1980's to only half (1 Mha) in 2000 (Table 35). The forest cover loss between 1985 and 2000 equals 2.8% per year in Peninsular, 2.9% per year in Sabah and 1.1% per year in Sarawak, which gives a total forest cover loss on peatland in Malaysia of 1.8% per year (Table 35).

Table 35: Peatland and forest cover in Malaysian

	Peatland area		Peatland forest cover			Peatland forest cover loss
	Rieley and Page, 2005 [a]	Hooijer et al., 2006	Rieley and Page, 2005	Hooijer et al., 2006 [c]	Hooijer et al., 2006 [c]	Hooijer et al., 2006
			Unknown [b]	1985	2000	1985-2000
	1000 ha		1000 ha	1000 ha		in %
- Peninsular	985	599	671	467	222	-2.8
- Sabah	86	172	86	148	74	-2.9
- Sarawak	1660	1272	1.400	967	750	-1.1
Total Malaysia	**2731**	**2043**	**2157**	**1582**	**1046**	**-1.8**

a – Rieley and Page, 2005 (based on Coulter, 1957; Tie and Kue, 1979 and Scott, 1989); same numbers presented by International Mire Conservation Group, 2004 (based on Law and Selvadurai, 1968; Wong, 1991 and Acres et al., 1975)

b – While the year is not given in Rieley and Page (2005), it can be estimated that this refers to around 1980/1981 because a study by UNDP Malaysia (2006) suggests that peatland forest cover on the peninsular was 671 000 ha in 1981, the same amount as suggest by Rieley and Page here.

c – Hooijer et al. (2006) could only give estimations of the forest cover of peatland in Malaysia and the data presented here should, therefore, not be used as precise results.

While forest cover on peatland has decreased, agricultural use of peatlands has increased over time. Agricultural use of peatland on the peninsular amounted to only 179 thousand ha in 1966 and increased to 314 thousand ha in 1984. The other studies show an increase in peatland use in Sarawak but it is difficult to compare the data because reference years are not presented. For Sabah, no information is given in those other studies.

Interesting to mention is also the study by Henson (2007), which estimates peatland use for palm oil production at 0.45 Mha in approximately 2006. This would represent 10% of the total land area under palm oil cultivation.

In March 2008 the Environment Ministry of Malaysia announced that peatland guidelines would be established. These guidelines would be based on the Peat Swamp Forest project for state governments to ensure conservation and sustainable use of peat swamp forest in Malaysia. However, the ministry is aware of the fact that the decision to follow these guidelines is up to each Malaysian state itself and it is unclear whether the different states would actually follow them.

Table 36: Peatland agriculture in Malaysia

	Peatland area	Peatland use for agriculture			
Sources:	Rieley and Page, 2005	IMCG, 2004	IMCG, 2004	Rieley and Page, 2005	Jamaludin, 2002
	Approx. 1989 1000 ha	1966	1984 1000 ha	unknown 1000 ha	unknown 1000 ha
Peninsular	985	179	314	314	314
Sabah	86	Not given	Not given	-	-
Sarawak	1660	Not given	56	260	555
Total Malaysia	2731	n/a	n/a	574	869

Note: IMCG - International Mire Conservation Group, 2004

7.5 Shrubland, Savannah and Grassland

According to the Global Land Cover Characteristics Database (GLCCD), shrubland, savannahs and grasslands made up 1 % of Malaysian land area in 1992/93 (Table 37).[32] An estimate for shrubs in Malaysia in 2000 from FRA 2000 indicates that this land category has been increasing in the past, shrublands increased more than twofold by 2000 (FAO, 2001a). It is unclear how savannah and grassland areas have changed over the past 15 years.

Imperata grassland

Information on *Imperata* grassland in Malaysia was obtained from the study of Garrity et al. (1997) in which it is estimated that grassland areas are much smaller than in the neighbouring countries Indonesia and the Philippines. It is estimated that there are approximately 200 000 ha of sheet *Imperata*[33] in Malaysia, of which 72 000 ha were found in Sarawak, 155 000 ha in Sabah and no significant areas on the Malaysian peninsular (Garrity et al., 1997). Including also smaller areas of grassland, Garrity et al. (1997) estimate that there are 0.5 Mha of Imperata grasslands in Malaysia. The total of 0.5 Mha is significantly larger than the amount of grassland determined by the interpretation of satellite images from 1992 (GLCCD) and it is unclear what the reasons for this difference are.

The Sabah Forestry Department suggests that in 1976 there were some 200 000 ha of degraded land in Sabah, which was mainly dominated by Imperata grassland (Sabah Forestry Department, 2008a).

Table 37: Shrubland, grassland and savannah in Malaysia

	1992/1993	2000
	1000 ha	
Shrubland	297	684 [a]
Savannah	29	
Grasslands	76	
Total	**402**	
Percentage of total land area	1%	

Source: 1992: Earthtrends, 2007c citing GLCCD;
2000: FAO, 2001a

a – The 2000 value for shrubland is taken be the same as the category "shrubs/trees" in the FAO Forest Resource Assessment 2000. The 2005 FRA does not distinguish this category anymore, so that 2005 values could not be provided.

7.6 Degraded Land

There is no clear, universally agreed upon definition of degraded land. Here the definition of the Food and Agriculture Organisation of the UN (2007a citing ISO, 1996) is applied which states that "land which due to natural processes or human activity is no longer available to sustain properly an economic function and / or the original ecological function." Moreover, in some studies degraded land was set equal with land that was invaded by grasses. In this study, grassland is not included directly in the category of degraded land as it is dealt with in the previous section "shrubland, savannahs and grassland".

GLASOD Data

[32] Scientific teams assessing the accuracy of GLCC found that a given area agreed with classification of GLCCD in only 60 to 80% of the cases (Earthtrends, Technical notes to Land Area Classification by Ecosystem Type, 2007).

[33] Sheet *Imperata* or mega-grassland are areas of grassland larger than 10000 ha a piece.

Estimating the degraded land in Malaysia is based primarily on the Global Assessment of Human Induced Soil Degradation (GLASOD) by the International Soil Reference and Information Centre (ISRIC) from 1990 (Oldeman et al., 1990). GLASOD is based on expert opinions from the 1980s and despite the fact that the data is so old, this is currently the only available global database on degraded land with which data for different countries can be compared. The results for Malaysia show that in total 5.5 Mha are considered degraded land, which equals nearly 17% of the total Malaysian land area. The bulk of this degraded land (4.8 Mha) is frequently severely affected by degradation (Table 38). This compares to Indonesia, which has 5.7 Mha of frequently severely degraded land. However, in addition, Indonesia also has 7 Mha of very frequently severely degraded land and another 7.4 Mha of dominantly very severely degraded land (see Appendix C). No land area was classified dominantly very severely degraded in Malaysia (Table 38).

Even after an extensive search for other sources on degraded land only one other source could be found which provides interesting information regarding degradation of land. This source is the national report to the Committee of the Review of the Implementation of the Convention to Combat Desertification (CRIC5) of the UNCCD (UNCCD, 2002). The study presents data for marginal soils in Malaysia in 2002. The category of marginal soils refers to soils "which are only recommended for agricultural development after adequate land improvement, and conservation works are carried out and a high level of management applied" (UNCCD, 2002). Peninsular Malaysia has 1.3 Mha, Sabah 4.3 Mha and Sarawak 2 Mha of marginal soils (UNCCD, 2002) so that the total for Malaysia is 7.6 Mha. The UNCCD data refers to marginal soils for agricultural production and it is not clear whether the soils or the land are also degraded. Some of the marginal land also includes steep and mountainous land, peat soils, acid sulphate soils and impoverished sandy beach soils.

Table 38: Land degradation in Malaysia based on GLASOD (1990)

Frequency	Infrequent	Common	Frequent	Very frequent	Dominant	**Total Degraded**	**Percentage of total land**
Severity			1000 ha				%
Moderate	46	-	628	-	-	674	2.1
Severe	-	-	4844	9	-	4853	14.7
Total	46	-	5471	9	-	5527	16.8

Source: FAO, 2008

7.7 Burnt and Barren Land

The amount of land affected by fires was reported by Kiam (2005) in the Malaysia country report for the FRA 2005 and refers to the occurrence of fire in the permanent forest estate in Malaysia. No information was obtained for fires affecting other land categories. The data is presented in Table 39 and shows that fires affected the largest land areas in 1998 and in 2002.

Table 39: Occurrence of fire in Malaysian permanent forest estate from 1990 to 2002

		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Fire occurrence	1000 ha	690	116	418	56	156	25	18	26	1646	27	6	297	1350

Source: Kiam, 2005

ABC and WCMC (1997) describes that in 1983 approximately 1 Mha of forests were affected by fires, most of which actually affecting logged-over forests. In the peninsular state of Selangor, barren and burnt land in 1966, 1981 and 1995 was documented. The percentage of land categorized as burnt and barren increased only slightly in those years and amounted to approximately 5%.

The major causes of fires in Malaysia are found to be improper peatland management, slash and burn activities and poor water management. Those causes and their effects are amplified during long dry spells (Ahmad, 2001). This effect is especially recognizable in years in which the El Niño phenomenon occurred: 1983, 1997/1998 and 2002.

7.8 Overview Of Land Use Change

Based on the data presented in the previous sections, an overview of LUC over the past 30 years (1975 to 2005) is made. This overview of LUC in Malaysia is based on many uncertainties in data and the unavailability thereof. As a result, the following assumptions are made in order to make an overview of LUC in Malaysia possible (Figure 24):

- *Forest area* is presented by applying forest area data from the Malaysian Economic Planning Unit (2008) even though it is unclear whether actual forest cover is presented in this dataset. All other sources were not suitable for this overview because they either do not reliably present forest cover (FAO FRA 2005 is based on legally assigned forest land rather then forest cover, see description above) or do not present a time series (Stibig and Malingreau (2003), who only present data for 2000 that is not comparable to other sources and years even though it is most likely a good indication of the actual forest cover).
- S*hrubland and savannah* are assumed to have remained constant over time as only little information is available. However, it is likely that changes in the shrubland and savannah area have occurred.
- *Grassland* is assumed to be constant at 0.5 Mha based on the study by Garrity et al. and includes micro grasslands (individual field level). While this is a simplification of the actual grassland area, there is no other information available.
- Data on *arable land, permanent crops without palm oil and permanent pastures* are taken from FAOSTAT. Data on permanent crops (without palm oil) includes natural rubber and is calculated by subtracting land area of oil palm (as described below) from the total permanent crop area.
- Data for *immature and mature oil palms* is taken from MPOB statistics as presented above.
- *Timber plantation* data used in the overview is based on total timber plantation area in 1980, 1990 and 2001 (FAO, 1984, FAO, 2002a, FAO Forestry Department, 2002). Average annual changes from 1980 to 1990 and from 1990 to 2001 are used to determine the area of timber plantations in all other years.
- Degraded land data is scarce and uncertain. It is assumed that the degraded land area in 1985 equals area determined by the GLASOD project. This amounts to 4.8 Mha. But, considering that the category *frequent* refers to a percentage cover in each polygon of between 11 and 25%, actually only (on average) 18% of the land area should be considered degraded. Therefore, degraded land in 1985 is assumed to amount to 0.8 Mha. As also the other sources on degraded land are difficult to interpret it is assumed here that the degraded land area remains constant. However, this assumption is simplified and based on the logging in the past it is likely that degradation of forest could have increased the area of degraded land.
- Besides the different land use categories, there is also some land left over, here called "*rest*" which does not fall in either of the categories. The rest category includes deforested forest which was not converted to any other land use (primarily agriculture, palm oil and timber plantations) and *land affected by fires*, which is not included as a separate category in the overview due to the very uncertain nature of the data found in literature. It also includes urban land, which is, however, small compared to the other categories. Moreover, logged-over forest may be included in this category, if the land has such low tree cover that it is not considered in *forest area* anymore. It is uncertain how this land is used - if it is used at all.

Figure 24 shows that forest area still makes up the largest share of all of Malaysia's land area. While forest area loss has slowed down in the past 15 years compared to the period 1975 - 1990 it is still occurring in Malaysia. Due to the uncertainty and lack of better data on forest cover for Malaysia, the past developments in forest area cannot reflect the quality of the existing forest; for example, forest area data does not distinguish between primary and secondary forest. This can be seen in above-presented data on a shift from primary to secondary forest, leaving the area of primary forest to amount to 3.8 Mha in 2005 (equivalent to only 20% of the total forest cover area). Figure 24 depicts the significant growth of palm oil plantations, which appears to occur at the expense of other permanent crops and the rest category. This confirms reports that old natural rubber, coconut and cocoa plantations are being replaced by palm oil plantations (Abdullah and Nakagoshi, 2007, Ming and Chandramohan, 2002) and that palm oil has also been planted on logged over forests with low standing biomass (severely degraded, logged over forest belongs to the category *rest*).

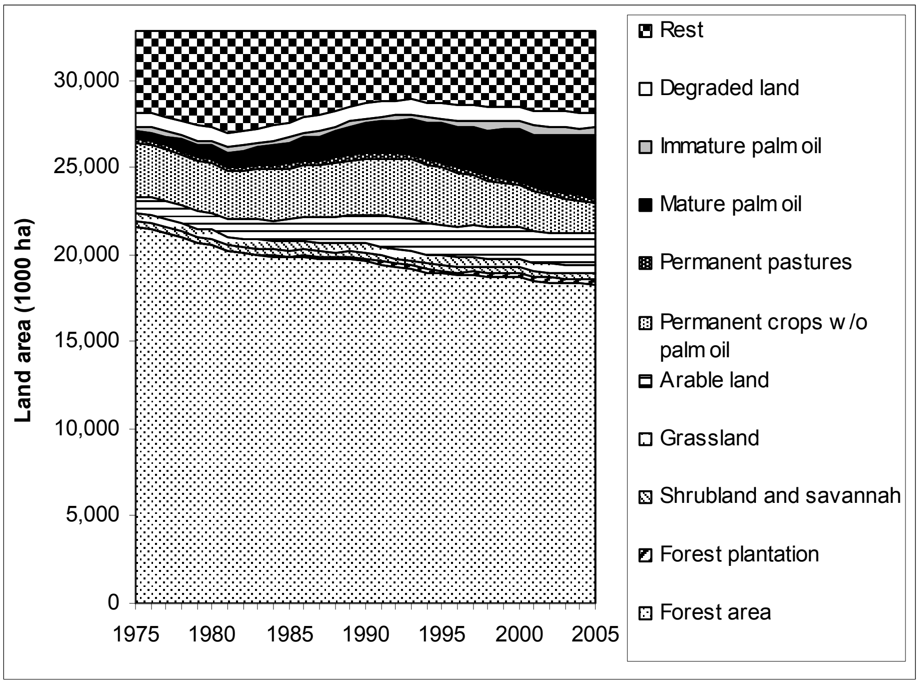


Figure 24: Overview of past land use change in Malaysia: 1975 to 2005

8 CAUSES AND DRIVERS OF LAND USE CHANGE IN MALAYSIA

In the previous chapter it was found that the expansion of palm oil production has seen a large change in area, while at the same time other permanent crops have decreased considerably. This is explained by palm oil being often planted on rubber or coconut plantations (see Figure 24). Also other changes in land use have taken place and in this chapter the direct causes (section 8.1) and underlying drivers of this change (section 8.2) will be analysed.

8.1 Direct Causes Of Land Use Change

Direct causes of LUC are activities and actions that directly change land use (Geist and Lambin, 2002). The direct causes are primarily wood extraction, agricultural expansion and infrastructure extension (see Figure 12). But direct causes of LUC in Malaysia also include expansion of timber plantations, shifting cultivation, forest and peat swamp forest fires and infrastructure expansion. Each of the direct causes and their importance in the overall LUC in Malaysia is explained in more detail below. While the causes are treated separately in the following sections, generally they are interlinked with one another and, when possible, these interlinkages are presented as well.

8.1.1 Logging

Logging of trees for timber purposes and for the conversion of forest to other land use types is directly linked to forest cover loss, which is due to trees being taken out. But it is also due to the destruction and resulting degradation of other trees and the understory by the large machinery and equipment that is applied for timber extraction.

Logging in Malaysia strongly increased in the early 1960's, peaked in 1992, then decreased rapidly until the turn of the millennium and since then somewhat stabilized at around 20 million m^3 per year (Figure 25). Initially, Sabah was the largest producer of logs in Malaysia, but since the beginning of the 1980's Sarawak has taken over this position. Thus, it comes as no surprise that for Sabah the largest agent of forest disturbance has been the timber industry. Logging has played a significant role in the degradation and loss of Malaysian forest in direct and indirect ways (McMorrow and Talip, 2001). First, logging generates secondary forests, which is allowed to be cleared under the Native Customary Rights (NCR)[34] (as opposed to clearing being prohibited in primary forests) (McMorrow and Talip, 2001).[35] Second, logging requires roads in order to access and transport the timber, which in turn facilitates shifting cultivation and permanent crop plantations to move deeper into the forest (McMorrow and Talip, 2001). Third, logging makes forests more flammable and therefore indirectly increases forest cover loss by fires (section 8.1.6) (McMorrow and Talip, 2001).

For Sarawak, Park and Seaton (1996) determined that in 1991 18 million m^3 were logged legally, which is double the estimated sustainable yield of Sarawak - 9.2 million m^3 according to the International Timber Trade Organization (ITTO) (Park and Seaton, 1996). Moreover, besides the legal logging, Park and Seaton (1996) determine that there are another 7 million m^3 of logs that were removed illegally.

According to Ozinga (2003), 39% of all timber used in the Malaysian timber industry in 2001 is illegally imported or illegally logged in Malaysia. Of the illegal imports a large share is likely to come from Indonesia, where illegal logging occurs frequently (MTC et al., 2007). Both descriptions of illegal logging in Sarawak and in Malaysia in general indicate that Figure 25 may be an underestimate of actual log production in Malaysia. However, there are also other sources that state that recent measures in enforcement improvement have help to

[34] NCR are the legal rights of native communities in Malaysia.
[35] It is not known whether there are currently any logging concessions in the primary forest of Malaysia.

reduce illegal logging to such a small level that it is insignificant compared to the extent of legal logging (MTC et al., 2007). No additional information was found to verify either one of these two views.

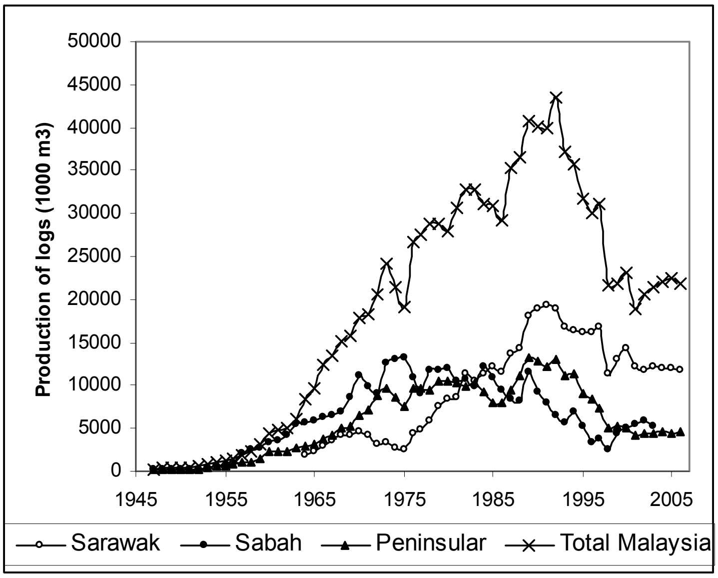


Figure 25: Production of logs in Malyasia between 1947 and 2006, by region
Source: Economic Planning Unit, 2008

As no information on the logging concession area is available for Malaysia, it is valuable to determine how much land would have to be clear cut in order to produce the amount of logs as presented by the Economic Planning Unit (Figure 25). Thus, assuming a log production of 22.4 million m^3 in Malaysia in 2005 (Economic Planning Unit, 2008) and an average growing stock by area in Malaysia of 251 m^3/ha (FAO, 2006a) results in 87.7 thousand hectare to be clear cut, which is equivalent to 0.4% of the total forest area. This compares well with the deforestation rate between 2000 and 2005 determined by the FAO. That this value is slightly lower can be explained by the fact that log production has been decreasing in recent years (Figure 25). While this area seems quite small, it must be remember that this area refers to total clear cut, which is not usually done. Instead, less trees are taken out per hectare so that a much larger area is affected and often degraded by logging. Moreover, also illegal logging is not accounted for in this calculation, which is likely to increase the area of forest land affected by logging.

8.1.2 Timber Plantations

The previous chapter has shown that timber plantations have been increasing in the past but still remain a small part of all LUC (section 7.1.3). Timber plantations are increasing mainly because there is a large demand for timber, while the government is trying to reduce logging in natural forests. No information on the type of land being converted to timber plantations could be obtained.

8.1.3 Palm Oil Expansion

Palm oil production and its land use have increased considerably in recent years. Between 1975 and 2005 the land area under palm oil production increased by 3.2 Mha, as explained in the previous chapter (section 7.3). One important factor of palm oil expansion in Malaysia is the increasing world demand for palm oil, which in turn can be partially explained by the lower price of palm oil compared to other vegetable oils. The increasing demand and the lower price are underlying drivers for palm oil production expansion and are described more in section 8.2.

8.1.4 Other Agricultural Land Expansion

Other agricultural land expansion in Malaysia is not an important factor in LUC in Malaysia because it has not changed as tremendously as in Indonesia. Other agricultural land expansion in Malaysia primarily refers to the expansion of arable land that increased from 1 Mha in 1975 to 1.8 Mha in 2005 (section 7.2). Other permanent crops (excluding palm oil) have seen a decrease in land area, which is often due to conversion to palm oil production, while permanent pastures have remained constant between 1975 and 2005.

8.1.5 Shifting Cultivation

Shifting cultivation is a direct cause of LUC because forested land is cleared and cultivated temporarily before it is abandoned and left to regenerate. In Malaysia, shifting agriculture has been seen as a cause of deforestation primarily in Sarawak and Sabah (McMorrow and Talip, 2001). In Borneo (including among others the Malaysian states of Sabah and Sarawak), shifting agriculture was practiced by a quarter to a third of the island's population: In 1989 it was estimated that 30 % of Sabah's population was involved in shifting cultivation (McMorrow and Talip, 2001). Due to national and state policies of rural poverty alleviation and agricultural modernisation this figure is likely to be lower today. The land area under shifting cultivation is estimated at only 22 000 ha, which is a significant reduction compared to 1.1 Mha in 1986 (McMorrow and Talip, 2001). McMorrow and Talip (2001) observe that the data on shifting cultivation depends highly on how shifting cultivation is defined and on the quality of the data source as the difficulty of distinguishing shifting cultivation from other forms of disturbance is high.

8.1.6 Forest and Peatland Forest Fires

In the previous chapter it was shown that it is difficult to determine the exact amount of land that is affected by fires because there is a problem in how severely a land area is affected by fire, i.e. lack of information on the length of the recuperation period and the subsequent management activities, and whether the same area is affected more than once by fires. Also, underground peat fires, which can exist for a long time after aboveground fires are stopped, are not accounted for in the data presented above (section 7.7). Despite data uncertainties, it is indisputable that forest fires are a direct cause of forest cover loss (see also section 4.1.5). And it is clear that forest fires are also a result of deforestation and forest degradation (Siscawati, undated). McMorrow and Talip (2001) confirm similarly for Sabah that logging makes forests more flammable because of increased wood debris, drier micro-climate and access roads that can be the origin of accidental ignition.

While forest and peatland forest fires are a direct cause of LUC, data shown in section 7.7 reveals that on average 372 000 ha were affected by fires each year (average for 1990 to 2002), which represents only 1.1% of the total land area of Malaysia and that fires can thus be considered only a small factor in LUC.

8.1.7 Infrastructure Extension

Another direct cause of forest decline is the extension of infrastructure through which deeper access into the forests is provided. As a result, logging operation and agricultural activities can move further into the forest without suffering from more difficult and more expensive transportation of timber and agricultural goods to the markets (CIFOR, 2007). However, also the contrary view is often reality: logging companies build roads so that timber is more easily and cheaply transported to the markets. Then, after road expansion for logging, settlers and oil palm developers have easier access to previously remote areas. The length of roads serves as an indicator of infrastructure expansion and shows for Malaysia that total length of roads increased from 20000 km in 1980 to nearly 90000 km in 2007 (Economic Planning Unit, 2008) (Figure 26).

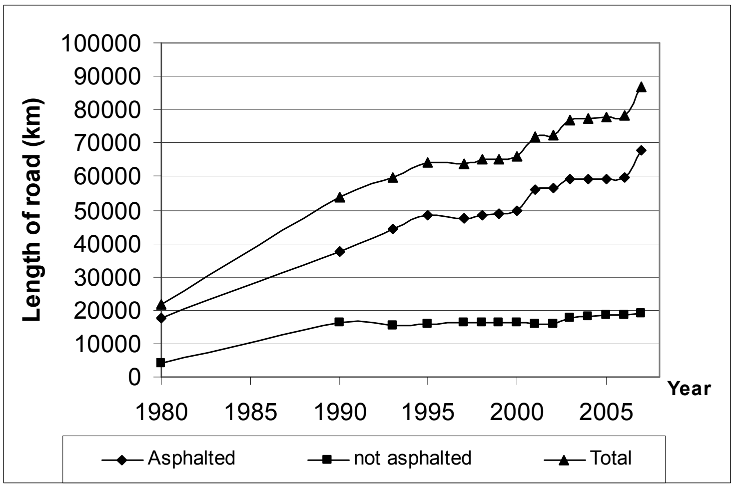


Figure 26: Length of road in Malaysia over time
Source:Economic Planning Unit, 2008

McMorrow and Talip (2001) show that the provision of road infrastructure made up a key driver in forest conversion in Sabah. It is interesting to note that road provision is a federal task and thereby gives the federal government some - even if small amount of – control over the pace of LUC (McMorrow and Talip, 2001).[36]

8.2 Underlying Drivers of Land Use Change

Underlying drivers are "fundamental social processes" that underpin the direct causes (Geist and Lambin, 2002). As with the direct causes of LUC, also the underlying drivers are multiple. An underlying factor can drive various direct causes and various underlying factors together can also drive only one direct cause. The following underlying drivers of LUC are assessed for Malaysia and their importance in the overall LUC is determined. The following underlying drivers are studied: demographic factors (here in terms of population growth and population density), economic factors (here in terms of agricultural and forestry prices, and economic growth) and policy and institutional factors.

8.2.1 Demographic Factors

Demographic factors - as underlying drivers of LUC - can best be described with population growth and population density. Population growth is linked to LUC by the additional land that is required for living, food production and resource extraction (both are direct causes of LUC), while population density is inversely related to forest cover (Sunderlin and Resosudarmo, 1996). Malaysia's population has grown from 5 million people in the 1930's to over 20 million in 2003, which presents a growth rate of 2.3 % per year. As Figure 27 shows this population growth was seen mainly on the peninsular, where today approximately three fourth of the total population live. Population density in Malaysia is relatively low compared to its neighbouring countries even though it has been increasing in the past. In 1970 the population density was 31 people per km^2, in 1994 population density in Malaysia amounted to 61 people per km^2 compared to 101 in Indonesia, 217 in the Philippines and 215 in Vietnam (Economic Planning Unit, 2008). Even though population density in Malaysia has increased, in 2002 it was still well below the neighbouring countries, namely 74 people per km^2 (Economic Planning Unit, 2008) and it is likely to be only a small factor in LUC in Malaysia.

McMorrow and Talip (2001) present population density data for Sabah and find a population density of 32 people per km^2 in 1995, which was only half of the total Malaysian population density. They find that population pressure has not been an important driver of land use change in Sabah. To the contrary, "the lack of labour has hindered agricultural development

[36] Land, forest and other natural resources are controlled by the Malaysian states, while the federal government can only give advice but take no decisions.

and forestry in eastern Sabah and necessitated the use of immigrant labour" (McMorrow and Talip, 2001 citing Sutton, 1988). It is unclear whether this also affected Sarawak and Peninsular Malaysia and if, how they have been affected.

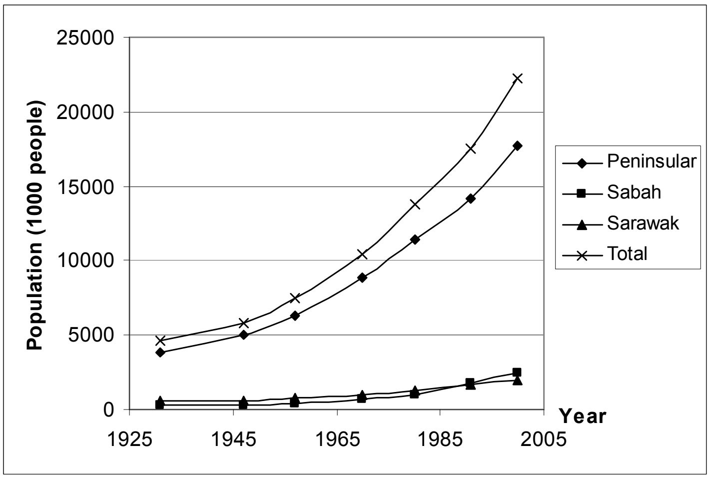


Figure 27: Malaysia's population over time, by region
Source: Economic Planning Unit, 2008

8.2.2 Agriculture and Forestry Prices

Agriculture and forestry prices also represent an underlying driver of LUC. A good example is the market price of palm oil, which is lower than most other vegetable oils (see also section 4.2.2). This is one factor in why palm oil is in high demand and its production is expanding (direct cause). Another reason is that the income that can be earned from producing palm oil is higher than from other food crops. Sunderlin and Resosudarmo (1996) suggest that smallholder net income in Indonesia would be twice as high on tree crop schemes as compared to food crop schemes once fully developed. Similarly, Chomitz et al. (2007 citing Tomich et al. 2005) find for Sumatra in 1997 that the net present value per hectare is 1 US$ for rubber agroforestry, 5 US$ for community forest management, while the net present value of oil palm cultivation amounts to 114 US$ and of unsustainable logging even to 1080 US$. This latter result also explains why illegal logging is so interesting from a financial point of view. Both of these results from Indonesia are likely to be similar for Malaysia as well.

In Malaysia in the late 1970's and early 1980's large areas of land were planted with cocoa, being seen as a way to economically develop rural Malaysia. The cocoa boom was replaced by the palm oil boom in the 1990's because of palm oil's higher world prices and lower labour costs than cocoa (McMorrow and Talip, 2001). Moreover, the currency devaluation of the Malaysia ringgit during the Southeast Asian economic crisis in 1997/1998, the importance of palm oil production in Malaysia was further strengthened because it was traded in US$ (McMorrow and Talip, 2001).

8.2.3 Economic Growth

For Malaysia it was found that GDP per capita, as one indicator of economic growth, has constantly increased over the past thirty years (except during the Southeast Asian economic crisis in 1997 when GDP per capita in current US$ plunged to equal the 1992 value) (Figure 28). Economic growth is associated with increased demand for goods, which in turn spurs the demand for natural resources and in particular for timber for construction (a direct cause of LUC). But, as will be seen in the next section, increased use of natural resources can also be seen as a driver of economic development and growth, which is why it is stressed in development policy in Malaysia (see next section).

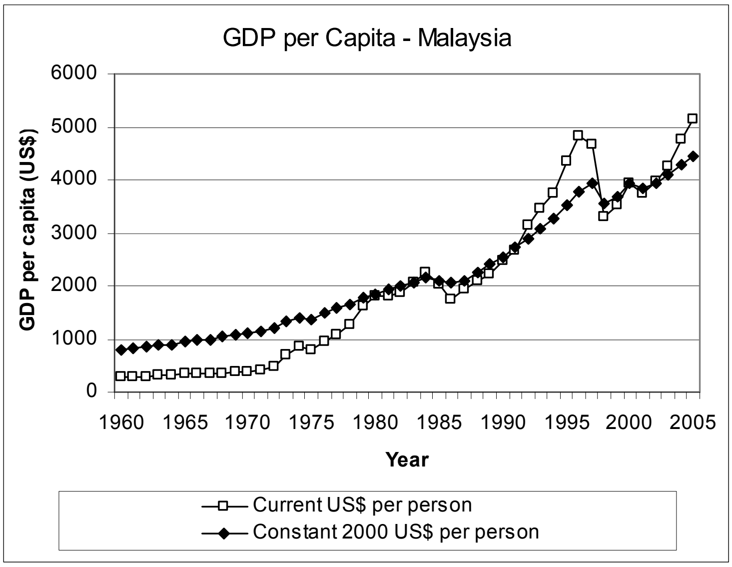


Figure 28: GDP per capita developments in Malaysia
Source: Earthtrends, 2007b citing World Bank - Development Data Group, 2007

Increased income generally goes hand in hand with an increasing and diversifying demand for food. This can be seen in, for example, increased dietary energy consumption per person from 2570 kcal/person/day in 1970 to 2870 kcal/person/day approximately thirty years later (Table 40), and in the increased meat consumption, which changed from 13 kg per person in 1961 to 51 kg per person in 2002 (Earthtrends, 2007a). Additional food demand and especially higher meat demand results in more agricultural production (and/or increased imports), which together can partially explain the increasing arable land area in Malaysia. It is difficult to pinpoint exact shares of additional food demand being met by imports, additional land use or yield increases. But it is clear that all factors have contributed. Besides an increase in land use by the agriculture industry (section 7.2), there was also an increase in yields and in food imports. FAO statistics show that yields on average increased by 2.4% per year in Malaysia, while some individual crops increased at an even higher rate (FAOSTAT, 2008b). Import statistics show that Malaysia is increasingly importing food, which can be seen best in the import of soybean cake and chicken. Chicken is the large import product according to available FAO STAT data (FAOSTAT, 2008d). Malaysia imported 2.5 million tonne in 1961, which increased to 3.6 million tonne in 2005. In 1961 no soybean cake was imported while by 2005 it had become the second largest import product with 0.8 million tonne (FAOSTAT, 2008d).

Table 40: Dietary energy, protein and fat consumption in Malaysia over time

		1969 - 1971	**1979 - 1981**	**1990 - 1992**	**1995 - 1997**	**2001 - 2003**
Dietary energy consumption	kcal/person/day	2570	2760	2830	2890	2870
Dietary protein consumption	g/person/day	52	59	68	76	75
Dietary fat consumption	g/person/day	56	78	97	86	84

Source: FAOSTAT, 2008a

8.2.4 Policy and Institutional Factors

Various policy and institutional factors are underlying drivers of LUC in Malaysia. They include the orientation of policy to use natural resources to finance foreign debts (originally only timber from natural forest but now also increasingly tree crops from plantations),[37] corruption, and land tenure conflicts caused by governmental allocation of concessions. In the following these factors are described.

The first factor is based on using forest resources for financing foreign debts and economic and social development of Malaysia. In the 1950's and 60's log production in all regions of

[37] Several issues are related to this (general) policy aspect. These are 1) timber revenue remaining within the state, 2) policy factors in Sabah and 3) the creation of PFE as a limit to LUC and are described below.

Malaysia and their export began to increase. One reason for focussing on forest resources as opposed to other resources is that timber revenues are collected by the state whereas the exploitation of state's oil or gas resources would generate revenue for the federal treasury (Drummond and Taylor, 1997), which is why state governments preferred timber extraction over other resource exploitation.

The policy factors of LUC are described in detail for Sabah by McMorrow and Talip (2001) who determine that the most important factors of deforestation and forest degradation are the national and state economic and social policies: "A policy of rapid economic growth based initially on timber and increasingly on agricultural exports has been the driving force behind decline of forest area and quality" (McMorrow and Talip, 2001). Three specific policy instruments were found by McMorrow and Talip to have played an important role in forest decline in Sabah: 1) land gazettement and alienation, 2) land capability classification and 3) land code. McMorrow and Talip (2001) describe the three policies as follows:

> Three policy instruments have played a significant role in explaining forest decline. First, land gazettement and alienation serve to partition the land resource between permanent forestry reserves and agriculture. They electively set an upper limit to forest loss although not to forest degradation. Second, the Land Capability Classification guides the allocation of land; the LCC maps help to explain the location of Forest Reserves and thus the broad spatial pattern of forest conversion on LCC classes II and III. Finally, the land code has provided an incentive for individuals and companies to convert leased forest land to agriculture. Land title rents and the proceeds from pre-logging of timber on alienated land are an economic incentive to the state to alienate more forested SL to agriculture.

The rural development policies of Sabah have been strongly influenced by the New Agricultural Policies, that aim at alleviating rural poverty and revitalising the agricultural sector (McMorrow and Talip, 2001) This in turn affected land use, and, with it, land cover and rate of forest decline because it resulted in more commercialisation of agriculture and forest conversion to tree crop estates in Sabah (McMorrow and Talip, 2001). Particularly palm oil will be further boosted in the near future because of its continuously increasing world demand and high prices compared to production costs so that also the state of Sabah can profit more.

Another aspect related to the policy factor being a driver of LUC, is the creation of permanent forest estate (PFE). The National Forestry Act of 1984 set up general rules on forestry while giving power over land resources to the individual states to act within these rules. In the National Forestry Act each state was recommended to set up 47% of its land as PFE, in which sound forest management, including harvesting and utilizing forest resources, could take place. Today, this PFE provides a ceiling to deforestation in the sense that PFE should maintain forest cover in the long term. However, two aspects cause doubt whether PFE will remain covered by forests. First, continuous logging in PFE has and will continue to cause degradation of the PFE and possible forest cover loss. And second, the area of PFE may not be kept at current levels due to stronger pressures on the government to free land for development.

The second factor to be described here relates to the insecurity and the often short length of timber concessions. Both of these issues cause concession holders to rapidly extract all marketable timber rather than considering sustainable harvesting and yields (Drummond and Taylor, 1997). Related is the frequently stated problem and underlying driver of LUC in Malaysia: corruption. Corruption can be found in the allocation of timber and tree crop concessions to political and business figures. According to Chin (1996 cited in Drummond and Taylor, 1997), the allocation of concession is used to "reward, influence and punish."

And a third factor is land tenure conflicts caused by governmental allocation of concessions in Malaysia. Especially in Sarawak many land tenure conflicts are occurring. Those are primarily due to logging, palm oil and tree plantation concession overlapping with Native Customary Rights claims (Colchester et al., 2007). Land tenure conflicts can cause clearing of forest to demonstrate use and thereby ownership, but sometimes it can spur arsonists to harm another group by fire.

8.3 Literature Overview of Causes and Drivers of Land Use Change

A good overview of causes and drivers of LUC in Malaysia is given by McMorrow and Talip (2001), who describe the direct causes of forest cover loss in Malaysia per region: Sabah and Sarawak were both primarily affected by timber extraction and shifting cultivation in the past while Peninsular Malaysia and in recent years increasingly in Sabah forest cover has been affected most by "agri-conversion" (McMorrow and Talip, 2001). This is the conversion of forest land to agricultural crops, which, as previously mentioned, is mainly the expansion of oil palm. McMorrow and Talip (2001) explain that the differences in the responsible factors for LUC in the different regions in Malaysia are primarily caused by the autonomy of the states in terms of land resources and the resulting varying (social and economic) development policies.

Abdullah and Nakagoshi (2007) confirm the significance of agri-conversion on Peninsular Malaysia and further distinguish the importance of different crops. They found that between 1966 and 1995 oil palm expansion was the most important factor in fragmentation of wetland forests while rubber plantations were found to be the most important factor in fragmentation of regular forests (Abdullah and Nakagoshi, 2007). While rubber has been an important factor in the past, since the beginning of the 1990's the area of rubber plantations has been decreasing (FAOSTAT, 2008b) so that it is likely to be a less important factor in deforestation in recent years and today.

9 PROJECTIONS OF FUTURE LAND USE CHANGE IN MALAYSIA

9.1 Projections of Future Palm Oil Production

Future palm oil production is projected on the basis of four different sources: 1) extrapolation of past trends of land cultivated with oil palm, 2) FAO projections of palm oil production, 3) projections of the Malaysian Palm Oil Board (MPOB as presented by Jalani et al., 2002) for land expansion and 4) expansion estimates made by the 9th Malaysia Plan (Economic Planning Unit, 2006). These projections are described below.

5. **Past Trends**: A trend for the area under oil palm cultivation is determined for 2020 from historic developments of land area under oil palm cultivation (MPOB, 2006): Projections are based on average annual expansion rates between 2000 and 2005, which was 4% for all of Malaysia but was composed of 2% on Peninsular Malaysia, 4% for Sabah and 10% for Sarawak. These growth rates are then used for determining the area under palm oil production in 2020 (including mature, damaged and immature).

6. **FAO**: The FAO projections for 2010 for oilseeds suggest a production increase of 3.8% per year for Malaysia (FAO, 2003). With given yields (depending on *base case* or *improved case*, see below), the mature palm area is determined. Projections for 2020 assume an annual production volume increase of also 3.8% after 2010. However, it is likely that production will slow down over time and that this percentage would be lower. But since no other information from FAO could be obtained, this percentage is used.

7. **MPOB**: The MPOB projections are based on the work of Jalani et al. (2002) as the original MPOB source could not be obtained. According to Jalani et al., MPOB projects that 4.7 Mha will be cultivated for palm oil production in 2010 and 5.1 Mha in 2020.

8. **9th Malaysia Plan**: The 9th Malaysia Plan, the economic development plan by the government, suggests that palm oil production would increase by 5.5% per year until 2010. This is assumed to continue also until 2020 even though it is likely that average annual growth will be lower in the longer term. However, because no other information is available regarding growth rates from 2010 to 2020.

For each projection two cases are studied, which differ from each other by the assumed yield and the share of immature and damaged palms in the total land area. The cases are *base case* and *improved case* and are described in more detail below.

Base case

Yields have continuously increased from 3.1 t ha^{-1} y^{-1} on average between 1975 and 1979 to 3.9 t ha^{-1} y^{-1} on average between 2000 and 2005. It is assumed that this increase will continue until 2020 in the same manner; that is, with an annual increase in yields of 0.7%. The resulting yield is 4.3 t ha^{-1} y^{-1} in 2020 and is applied to all projections. An exception is made for the MPOB projections which mention a yield of 3.8 t ha^{-1} y^{-1} in 2020; this yield is applied only in the MPOB projections.

The *immature and damaged*[38] area is also included in determining the land area. The "past trends" projection is based on extrapolation of the total area of palm oil plantations, thus including immature and damaged area. All other projections apply the same immature and damaged share as in 2005, which was 10% for Peninsular Malaysia, 7% for Sabah, 19% for

[38] No information could be found regarding the amount of damaged palms in Malaysia but the term is included here for consistency in comparison with Indonesia. It can be assumed that the damaged palm area is very small, in Indonesia it amounted to approximately 1% for all types of producers in 2005 (IPOC, 2005), which is why it can be neglected in the rest of this analysis.

Sarawak and 10% for all of Malaysia (MPOB, 2006). The currently very lower immature rate is explained by the low replanting which is due to 1) initially high palm oil prices that made it more profitable to keep old palms and 2) subsequently low prices, which further delayed replanting because of the uncertainty of investment and markets

Improved Case

The projections with improvements assume that the total production volume in 2020 remains constant compared to the *base case* projections but that yields are improved and that a 20% share of immature palms is applied. These measures are applied in order to see how much less land will be required to obtain the same production level as in the *base case*. Assuming that production volume remains constant, the required mature area is determined with the improved yield. This land area is then used to calculate the area of immature palms by applying the percentage of immature palms in the total land area under palm oil cultivation (see below).

In the projections with an improved yield it is assumed that *yields* can increase to 6.1 t ha^{-1} y^{-1} in 2020, which is equivalent to an annual increase of 3% as suggested by Dros (2003).[39] While these yields are significantly lower than the visionary yields provided by MPOB (8.8 t ha^{-1} y^{-1} in 2020), these yields appear to be more realistic.

The rather low share of *immature* palms in Malaysia in 2005 is likely to increase in the future as MPOB is campaigning for faster replanting because the low replanting rate has been seen as one reason for lower yields than expected. Jalani et al. (2002) suggest that an appropriate share for the area of immature and young palms is 20%. The age group "immature and young palms" includes palms with the age 1 to 7 years so that the share of immature only is likely to be even lower than 20%.[40] It is assumed that immature and damaged palms account for 20% of all area under oil palm cultivation in the future in Malaysia.

Results of Projections

Results of the projections for palm oil expansion by 2020 are presented in Table 41. Large variation in total land area required for the different projections can be seen, ranging from a total land use by the palm oil sector of 5.1 Mha (MPOB) to 8.6 Mha (9th Malaysia Plan), with the past trends extrapolation and the FAO projections falling in between those extremes (7 Mha and 6.8 Mha, respectively).

When yields are increased and a share of 20% for immature palms is assumed, up to 30% of the land under oil palm cultivation can be avoided in all projections compared to the base case presented above all projections (Table 41). Land area occupied by oil palm now ranges from 3.6 Mha in the MPOB projection (a reduction in land use by 0.5 Mha compared to 2005) to 6.9 Mha based on the projections of the 9th Malaysia Plan.

It is interesting to notice an important difference between Malaysia and Indonesia here: While the Indonesian share of immature palms in 2005 amounts to 29%, the Malaysian equivalent was 10%. As a result, the improvement case, in which a share of immature palms of 20% is assumed, causes Indonesian immature palm oil land area to decrease while in Malaysia it causes an increase. Because of this increase in the share of immature palms in Malaysia the reduction in land area is not as large as in Indonesia. However, as Jalani et al. (2002) point out, a higher share of immature palm than the current one in Malaysia is required in order to improve yields; i.e. with an increased share in immature palms also more higher yielding palms are introduced with which yields can be improved.

[39] This increase can be made possible by implementing better management practices, which help increasing the yield of fresh fruit bunches and the oil extraction rate (OER).

[40] Young palms (age 3/4 to 7 years) are already productive (even though lower yields than older, mature palms) and therefore, belong to the category "mature palms".

Table 41: Projections for total land use by palm oil production in 2020

		Past trends	MPOB	FAO	9th MY Plan[c]
BASE CASE					
CPO production	1000 t	27036	17350	26178	33402
Yield	$t\ ha^{-1}y^{-1}$	4.3	3.8[b]	4.3	4.3
Mature area	1000 ha	6287	4590	6088	7768
Immature area	1000 ha	699	510	676	863
Malaysia total	1000 ha	6986	5100	6764	8631
Additional land requirements	*1000 ha*	*2936*	*1050*	*2714*	*4581*
Average annual expansion	% / y	4	2	3	5
Average annual expansion	1000 ha	196	70	181	305
IMPROVED CASE[a]					
CPO production	1000 t	27036	17350	26178	33402
Yield	$t\ ha^{-1}y^{-1}$	6.1	6.1	6.1	6.1
Mature area	1000 ha	4450	2855	4308	5497
Immature area	1000 ha	1112	714	1077	1374
Malaysia total	1000 ha	5562	3569	5386	6872
Additional land requirements	*1000 ha*	*1512*	*-481*	*1336*	*2822*
Average annual expansion	% / y	2	-1	2	4
Average annual expansion	1000 ha	101	-32	89	188
Reduction from base case	%	20	30	20	20
35:25 VISION					
Malaysia total	1000 ha	3867	2823	3718	4745
Additional land requirements	*1000 ha*	*-183*	*-1227*	*-332*	*695*

a – The improved case refers to both improvements in yields and a share of immature palms of 20% as described in the text.

b – The yield in the MPOB projection is slightly lower than in the others because this is the yield given by MPOB, while other studies do not provide a yield

c – While the 9th Malaysia Plan does provide information on yields, it was chosen not to include this in these calculations of the base case because the envisioned yields of fresh fruit bunches are much higher than the past trends and it is unclear whether such yields could be achieved without additional investments into yield improvements, which is here considered to occur in the improved case (Economic Planning Unit, 2006). For comparison reason the land area required if these yields are actually reached are presented in the text.

Besides the projections made by the Malaysian Palm Oil Board (MPOB), the MPOB also has visionary targets for the yield of fresh fruit bunches to increase to 35 $t\ ha^{-1}\ y^{-1}$ and the oil extraction rate to increase to 25% in 2020. This so-called "35:25 Vision" would result in an oil yield of 8.8 $t\ ha^{-1}\ y^{-1}$. As these yields require an even higher annual increase than proposed by Dros (2003) and the likeliness of its occurrence is doubted, these yields are not applied in the improved case. However, to give an idea of the land use under such conditions, Table 41 shows that, in all but the 9th Malaysia Plan, total land requirements of the palm oil sector would be lower than in 2005 the same amount of CPO is produced as projected in the base case. The 9th Malaysia Plan projection would still require an additional 0.7 Mha, but this is a significant reduction from the additional 4.6 Mha needed in the base case.

Comparing the expansion projections (Table 41) to the past average annual expansion, which was 0.14 Mha per year between 1990 and 2005, it shows that the base case projections require a doubling of the past expansion rate. However, annual expansion is restricted by the limited amounts of required seeds, skilled labour, logistics, equipment and machinery. It is unclear what the maximum technically feasible area of average annual expansion (and replanting) is for Malaysia, which is why it is difficult to determine which of these projections could actually be technically feasible. Thus, despite high ambitions for expansion and an increasing demand for palm oil, it may not even be technically feasible to expand on such as large scale as suggested by the 9th Malaysia Plan.

9.2 Reference System

With the three projections for future reference land use (section 2.4 and Appendix B) available land for palm oil production until 2020 is determined. Table 42 presents the categories in which land is freed and the amount of land. It can be seen that in the *Business as usual* reference land use most of the available land comes from degraded land while deforested land and freed agricultural land together make up slightly less than degraded land. Due to not accounting for land from deforestation in the *Small Improvements* reference land use, available land decreases. Available land decreases further in the *Sustainability* reference land use because agricultural land – actually arable land – is assumed to slightly increase so that less land is available for other uses.

Table 42: Land availability in 2020 under different projections

	Reference land use projection		
	Business as usual	*Small improvements*	*Sustainability*
		1000 ha	
Deforested land [a]	525	0	0
Agriculture	567	567	-120
Timber plantations	-159	-159	-159
Degraded land	1372	1372	1372
Total land available	**2305**	**1780**	**1093**

Note: A negative number refers to additional land required in this category, while a positive number refers to land made available in this category that can be used for oil palm production

[a] – including deforestation on conversion forest

9.3 Land Balance

The land requirements under the different reference land use projections (Table 42) is matched with the required land for each oil palm expansion projection[41] in order to see whether enough land for the projected expansion is available. The results of this matching are presented in Table 43. In the table, positive numbers refer to land that is remaining after palm oil expansion, i.e. surplus land, and a negative number refers to the shortcomings of land for palm oil, i.e. land shortage.

The main results of the matching of required land with available land (Table 43) can be summarised as follows:

- Even if deforestation is allowed to continue as in the past not enough land is made available for most palm oil expansion projections. The few oil palm projections that are feasible with respect to land availability in Malaysia are the MPOB base case and improved case for all reference land use systems and the FAO and past trend projections of the improved case in the *Business as Usual* and *Small Improvements* reference land use system.
- The highest land shortages amount to more than 3 Mha in the 9th Malaysia Plan base case. But even with improvements, the land shortages amount to more than 1.7 Mha.
- If expansion does occur as projected (despite limitations found in this study), this will be only possible at the cost of forest cover, i.e. increased deforestation. The larger the projected expansion, the less sustainable the expansion will be.

Interesting to note also is that the FAO projections are not feasible in most reference land use systems – except when improvements take place and the *Business as Usual* reference land use system occurs. One reason for why the FAO projections for 2020 are not feasible (without increased deforestation) is that it is here assumed that the projections until 2010 are also valid until 2020. If considering FAO expansion projection only until 2010 an additional land requirement of 960 thousand hectare would be required. This is a feasible scenario as degraded land amounts to more than 1 Mha. However, only little land would then be available for palm oil expansion after 2010.

[41] Only the additional land that is required in 2020 is used here as it is assumed that land, which is now already in use for palm oil production, remains cultivated with oil palm.

Table 43: Land balance for Malaysia in 2020

Palm oil projections		Reference land use projection: *Business as usual* (1000 ha)	*Small improvements*	*Sustainability*
Past trends	base	-631	-1,156	-1,843
	improved [a]	754	229	-458
MPOB	base	1,255	730	43
	improved	2,267	1,742	1,054
FAO	base	-362	-887	-1,574
	improved	970	445	-242
9th MY Plan	base	-2,215	-2,740	-3,427
	improved	-516	-1,041	-1,728

Note: positive numbers refer to land that is remaining after palm oil expansion (surplus land); a negative number refers to the shortcomings of land for palm oil (shortage in land); the grey fields refer to the two cases which are studied in more detail below.
[a] – improved projection includes improved yields as well as a 20% share of immature palms

From all the projections presented above, two are chosen and their LUC are presented in Figure 29. The base case of the FAO projection with the *Business as usual* reference land use (Figure 29 – left) shows how the continued increase in palm oil expansion can be mainly met by the conversion of other permanent crops to palm oil, while also deforested land and a small amount of degraded land is used. The improved case of the MPOB projection with the *Sustainability* reference land use (Figure 29 – right) demonstrates that a total decrease in land cultivated with oil palms allows this land to be used for other agricultural purposes. Also, an increase in the rest category is seen, implying that part of the land freed from palm oil production may remain unused. However, this can be changed with appropriate policy to increase forested land instead. If this additional land (1 Mha as presented in Table 43) would also be used for palm oil production and a CPO yield of 6.1 t ha^{-1} y^{-1} is assumed then an additional 6 million tonne CPO could be produced each year. Together with the increase in production projected by MPOB, this would lead to an increase in production of approximately 9 million tonne CPO compared to 2020. So, despite many projections not being feasible in Malaysia, a considerable increase in production is still possible in a sustainable manner.

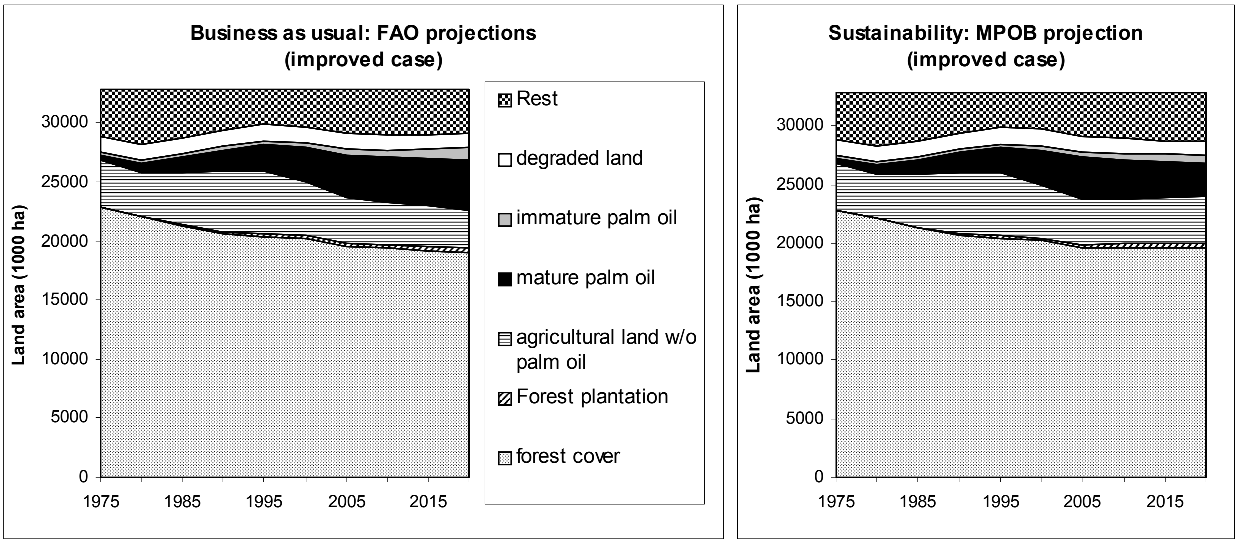


Figure 29: Land use change in Malaysia under two different projections: 1975 to 2020

Another important aspect of palm oil expansion is the use of peatland. In the reference land use projections *Business-As-Usual* and *Small Improvements* peatland may be converted to palm oil plantations. Table 44 presents the peatland areas being used for palm oil production expansion in 2020. It can be seen that up to 0.15 Mha of peatland may be used for palm oil production in the FAO and past trends improved case, the base case MPOB projection would require at least 0.09 Mha of peatland while the MPOB projections with improved yields would use no additional peatland in 2020 compared to 2005 – the main reason being that actually less land will be required than currently used.

Table 44: Additional peatland used by palm oil production

		Business as usual	Small improvements
		1000 ha	
Past trends	base case	Not possible [a]	Not possible
	improved case	156	87
MPOB	base case	121	87
	improved case	0	0
FAO	base case	Not possible	Not possible
	improved case	156	87

Note: Use of peatland in the sustainability reference land use projection is not allowed because of the unsustainability of draining peatlands and converting them to crop production.
The 9th Malaysia Plan projection is not shown here because none of the cases are possible.
a – "not possible" refers to those combinations of palm oil expansion projections and reference land use systems that have a negative land balance, i.e. not enough land is available to make this combination feasible. While the amount of peatland used in these systems could be determined for the maximum possible expansion, this would be misleading because the peatland area shown would be lower than if enough land was available.

Regional expansion of palm oil

The future expansion of palm oil in Malaysia has so far been determined for a national level. However, it is important to consider where in Malaysia this expansion will occur. In literature it is mainly suggested that future expansion will occur primarily in Sabah and Sarawak (Figure 30) because suitable soils in Peninsular Malaysia are already used and prices of land are much higher (Teoh, 2000). However, it appears this is also the case for Sabah, where future plantations are likely to be located on less suitable soils (Teoh, 2000). Teoh (2000) explains that

> "In Sarawak, about 2.5 million ha are considered suitable for agricultural development (Abang Helmi, 1998), but they are mainly on hilly or steep terrain or peat swamps. Areas with more than 25° slopes are unsuitable for oil palms. A survey conducted by PORIM in 1995 indicated that about 599,000 ha are suitable for oil palm cultivation in Sarawak; 75% of this is located in Division 4. About 3.38 million ha have been classified as marginally suitable, of which 1.55 million ha or 46% is peat soil. The survey also showed that 89% of the peat swamp is under deep peat."

However, Teoh continues, much of the suitable land in Sarawak is claimed under the Native Customary Rights (NCR), which amounts to about 1.5 Mha. According to Teoh (2000), much of this land has a low productivity or is left abandoned as a result of shifting agriculture. However, if this land was to be used for oil palm plantations, tenure issues need to be investigated first in order to avoid more land tenure and ownership conflicts.

The matching of available land with land requirements for palm oil expansion on a regional scale also needs to account for the spatial distribution of degraded land and its severity of degradation if this is where palm oil production should occur. Because only little is known about the exact location of degraded land and because there are also many other factors, which will influence the expansion of oil palm, such as the allocation and location of palm oil concessions, regional expansion was not be determined in this study.

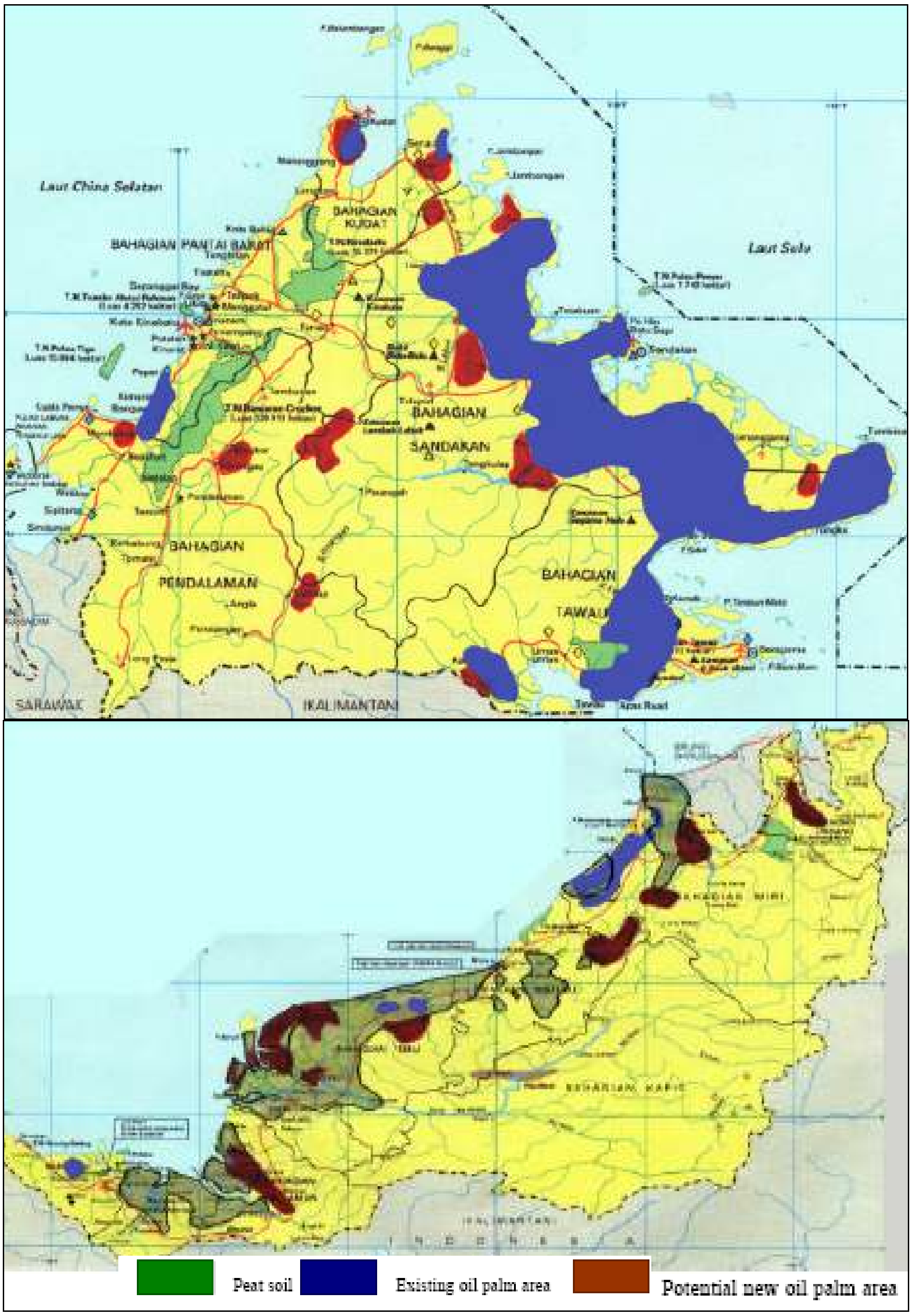


Figure 30: Existing and potential new oil palm areas in Sabah (top) and Sarawak (bottom)
Source: Teoh, 2000

10 GHG EMISSIONS FROM LAND USE CHANGE IN MALAYSIA

In sustainability discussions the greenhouse gas (GHG) balance of bioenergy is an important sustainability criterion. This is because the presumed GHG emission savings compared to fossil energy are a key driver for increasing bioenergy consumption in Europe and many other countries. However, it cannot simply be assumed that bioenergy results in GHG savings as the LUC associated with biomass and inputs to production such as fossil fuels for machinery, fertiliser and pesticides can all create GHG emissions (Reinhardt et al., 2007, Dornburg and Faaij, 2005, van Dam et al., 2004). Especially LUC has been found to largely influence the GHG balance (Reinhardt et al., 2007, Hooijer et al., 2006, Reijnders and Huijbregts, 2008). As explained in the approach section, only the GHG emissions from LUC associated with palm oil production are studied.

The annual GHG emissions from only LUC as a result of palm oil production expansion in Malaysia are presented in Table 45. The results show only those emissions that are caused by future LUC as a result of palm oil production expansion because LUC is the focus of this study. Not included are emissions from current land use under oil palm cultivation as it is not known how much forested land, logged over forest, degraded land or peatland was converted to palm oil. In addition it can be assumed that these emissions are already accounted for the total land use and forestry emissions in Malaysia 2005 with which the calculated emissions are compared (Table 46).

Table 45: Annual GHG emissions from LUC as a result of palm oil expansion until 2020

		Reference land use projection		
		Business as usual	*Small improvements*	*Sustainability*
Palm oil projection		million tonne CO_2-eq / year		
Past trends	base case	Not possible [b]	Not possible	Not possible
	improved case	23.1	7.2	Not possible
MPOB	base case	18.9	9.9	-5.7
	improved case	0.4	0.4	-0.2
FAO	base case	Not possible	Not possible	Not possible
	improved case	24.3	8.3	Not possible

[a] – This combination of reference land use projection and palm oil expansion projection is not possible due to lower land availability than land required for expansion (see Table 21).

Note: not shown is the 9th Malaysia Plan projection as it was determined in the previous section that the projections are not feasible in the three reference land use projections. However, it should be noted that emissions are higher than those feasible projections because of larger land requirements.

b – "not possible" refers to those combinations of palm oil expansion projections and reference land use systems that have a negative land balance, i.e. not enough land is available to make this combination feasible. While the GHG emissions caused by the palm oil expansion could be determined for the maximum possible expansion, this would be misleading because the emissions would be lower than if enough land was actually available. Therefore, it is chosen here, not to show the GHG emissions of those cases that are not feasible.

Emissions from the MPOB base case according to the *Business as usual* reference land use would be equivalent to 2.7% of the total land use and forestry emissions in Malaysia in 2005 or 9% of all Dutch emissions in the same year (Table 46). Emissions from the FAO projections are slightly higher than those of the MPOB projections in the *Business as usual* reference land use system but slightly lower tin the *Small improvements* reference land use system. It is interesting to note that emissions are more negative in the MPOB base case than in the MPOB improved case in the *Sustainability* reference land use system. The reason is that more degraded land is used in the base case and therefore more CO_2 can be sequestered from the atmosphere than in the improved case. This result is problematic because it gives a positive connotation to large land requirements for palm oil production. However, it must be stressed that if land requirements are lower (as in the improved case) more degraded land could be used for reforestation and thereby obtain much larger carbon absorption than a palm oil plantation. Thus, a different allocation of these emissions or CO_2 absorption would adjust this outcome. It was chosen not to include this here as reforestation will have to be increased strongly from its current level, which in turn requires stronger involvement of the Indonesian government, and it is not certain whether this will actually happen.

Table 46: Comparing GHG emissions from LUC as a result of palm oil expansion with emissions from LUC in 2005 in Malaysia and with total emissions from the Netherlands in 2005

		Reference land use projection					
		Business as usual		Small improvements		Sustainability	
		Malaysia LUC 2005	NL total 2005	Malaysia LUC 2005	NL total 2005	Malaysia LUC 2005	NL total 2005
Palm oil projection		%					
Past trends	base case	not possible	not possible	not possible	not possible	not possible	not possible
	improved case	3.3	10.8	1.0	3.3	not possible	not possible
MPOB	base case	2.7	8.8	1.4	4.6	-0.8	-2.6
	improved case	0.1	0.2	0.1	0.2	0.0	-0.1
FAO	base case	not possible	not possible	not possible	not possible	not possible	not possible
	improved case	3.5	11.3	1.2	3.9	not possible	not possible

Note: Emissions from LUC in 2005 in Malaysia amount to 699 million tonne CO_2-eq (Trines et al., 2006) and total emissions from the Netherlands in 2005 amount to 215 million tonne CO_2-eq (Brandes et al., 2007).
9th Malaysia plan projections are not shown because none of the possible cases is possible.

11 DISCUSSIONS

Consistent data on LUC in Indonesia and Malaysia proved to be difficult to obtain. The main reason can be found in that no single source possesses data on all land use categories and their developments over time, and that land use in different years was determined by different groups with varying methods. This resulted in various sources showing, at times largely, different outcomes, making an overview of LUC over time difficult. An additional problem of using various sources is the lack of clear definitions of land use categories or, in a number of cases, no mentioning of the definitions at all. These definitions, however, are necessary to ensure that outputs from different studies are comparable.

The lack of data was also reflected in determining the relationships between causes and effects of LUC. In order to better understand the causes and effects, it would be best to assess the chronological chain of events. This could be possible by analysing satellite images of Indonesia and Malaysia for various years. However, the very large data and time requirements exceeded the scope of this study.

The lack of data was also reflected in the attempt to analyse sub-national LUC. While some data on sub-national land use could be obtained for specific years, too much data was missing to establish time series for the different regions. As a consequence, an analysis of regional land use development in Indonesia and Malaysia in the future was not conducted. Similarly, Indonesian sub-national causes and underlying factors could not be determined due to the lack of data. More information on the sub-national causes and drivers was available for Malaysia, where several case studies on each of the three regions provided the necessary information.

The projections of palm oil expansion applied two cases, 1) the *base case* with past trend extrapolation of yields in Indonesia and in Malaysia[42] and current shares of immature palms; and 2) the *improved case* with improved yields and a share of immature palms of 20%. As it was shown that the increased yields cause the largest reduction in land requirements in the improved case, it is important to discuss the likeliness of the yield improvements to actually take place. It was shown that the projected yields for Indonesia are still low compared to good commercial yields already obtained in Malaysia now and compared to the theoretical yield. The latter is also true for the projections made for Malaysia, which are still far from the theoretical yield. Despite the differences to the theoretical yield, it is questionable whether yields can actually be increased by on average 3% each year because of the stagnant yields in the past in Indonesia and because of an annual yield increase of less than 1% in the past in Malaysia. Therefore, if these yield improvements are to be realised in both countries, strategies need to be determined with which such strong yield increases can be achieved. Jalani et al. (2002) have done exactly that for Malaysia in order to make it possible to reach the visionary target of 8.8 tonne CPO per hectare per year in 2020. Many of these suggestions are also appropriate for Indonesia; Jalani et al.'s suggestions for the *short term* are as follows (Jalani et al., 2002):

- Apply appropriate fertiliser dosages, timings and methods;
- Practise good harvesting standards (only ripe bunches) and collect all loose fruits;
- Quickly transport all ripe bunches and loose fruits to the mill; and
- Practise an appropriate replanting programme so that share of immature palms does not become too low.

For the *medium* to *long term* Jalani et al. (2002) suggest to

- Continue an active replanting programme to obtain an appropriate age profile, which is suggested to be 20% immature-young (1-7 years), 70% mature (8-19 years) and 10% old (> 20 years) palms;

[42] Yields in Indonesia have been stagnating, which is why the projected yield is the same as the current yield in Indonesia.

- Plant the latest high yielding and resource-efficient planting materials of both conventional and clonal materials;
- Apply the latest agronomic inputs using precision agriculture practices;
- Increase mechanisation to further improve labour productivity and operational efficiency to reduce cost;
- Apply pragmatic and innovative plantation management practices; and
- Conduct effective extension programmes to the various upstream sectors of the industry.[43]

Reaching the yield target for 2020 will depend largely on how quickly and how widespread these improvement strategies are implemented.

The projections have shown that in most cases enough degraded land is available on which oil palm expansion could take place. However, the use of degraded land for palm oil production is likely to result in lower yields (which would cause more land to be needed than determined here) or increased fertiliser application in order to improve yields.[44] However, this is not further investigated as only limited information on yields on degraded land is available. Moreover it needs to be noted that this land is likely to be already used in some form or another and that before expansion takes place on such land, first an assessment of land ownership, rights and tenure needs to be made. This is necessary in order to avoid land tenure/ownership conflicts with the current users but also to avoid causing indirect LUC by forcing the current users of degraded land to move into other areas, possibly forested land.

Two other aspects for discussion arise out of using degraded land. Firstly, there is the availability of degraded land for palm oil production: While many studies have shown that there are large areas of land which are degraded and potentially available for use in palm oil production in Indonesia, this needs to be verified in the field. Often, even marginal and degraded land is still used in some way by the local population, which needs to be taken into consideration when determining how much degraded land is actually available for palm oil production. Using degraded land should ensure that it does not cause land tenure conflicts with the current users or violations of human rights. While much less degraded land seems to exist in Malaysia, this issue is similarly important there. Secondly, the additional measures for making degraded land economically interesting for palm oil producers could also have an impact on human health and the immediate environment, for example by the increased use of fertiliser (in order to increase the lower yields of degraded land) and of herbicides during the preparation phase of the plantation.

For Indonesia and Malaysia the land balance and the GHG emissions of each scenario (as a result of combining a palm oil expansion projection with one of the three estimated reference land use cases) are highly dependent on the assumptions that were made when setting up the projections. By presenting the *Business-As-Usual* reference land use case as one extreme and the *Sustainability* reference land use case as the other extreme, it is likely that future developments of LUC will occur somewhere in between the given projections.

[43] One additional strategy is mentioned by Jalani et al., which is excluded here because it refers to using class 1 and 2 soils (i.e. the most suitable soils for palm oil production according to Malaysian suitability classification). The reason for excluding this strategy is that this study suggests using degraded and marginal land, which may not always fall in class 1 and 2 soils.

[44] Corley and Tinker (Corley and Tinker, 2003 citing Hartkey 1988) state that "there is no reason why land that has become overgrown with weeds and grass [i.e. *Imperata* grassland on degraded land], possibly after exhaustive food cropping, should not be converted to satisfactory oil palm plantations, but if much soil fertility has been lost it may require special treatment with fertilisers."

12 CONCLUSIONS AND RECOMMENDATIONS

While large scale LUC has occurred both in Indonesia and Malaysia over the past 30 years (Figure 31), the countries differ in the actual changes that took place. In **Indonesia the largest change has occurred in forest covered land** (a decrease from 130 Mha in 1975 to 86 million in 2003), while agricultural land has increased (from 38 Mha in 1975 to 48 million in 2005) – including an increase of land utilised by palm oil production (from 0.2 Mha in 1975 to 5.5 Mha in 2005 and even further to 6.1 Mha in 2006). In **Malaysia** deforestation was very strong until the beginning of the 1990's, slowed down considerably since then but still happens today. **The largest change in land use was seen in land cultivated for palm oil, which increased from 0.6 Mha in 1975 to 2 Mha in 1990 and 4 Mha in 2005**, while other permanent crops, primarily natural rubber and coconut plantations decreased strongly since the beginning of the 1990's (at a large part being replaced by palm oil).

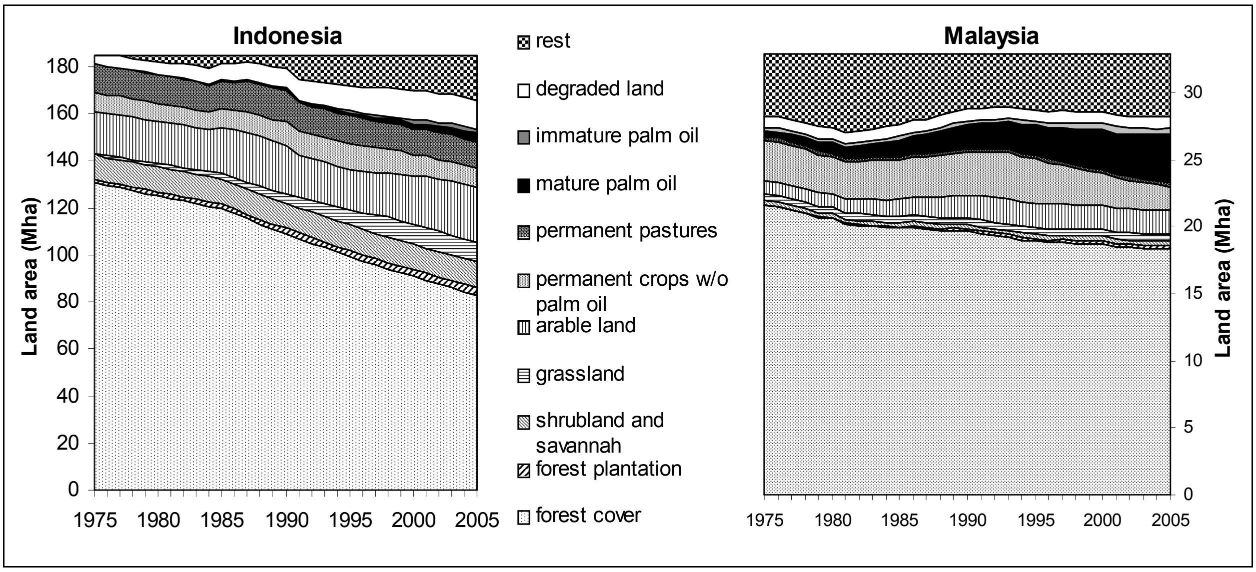


Figure 31: Overview of past land use change in Indonesia (left) and Malaysia (right) from 1975 to 2005

Making an overview of past developments in land use in Indonesia also highlighted that there are different forest categories and that making a distinction between, on the one hand, the governmentally assigned land to function as forest and, on the other hand, forest cover is important for better understanding the actual changes in Indonesian forest. The difference between forest land and forest cover in Malaysia was more difficult to determine than in Indonesia because of less data and less reliable data on forest cover.

The LUC data also showed that, while there has been much talk about degraded land and its use for future palm oil expansion, data about the amount and location of this degraded land is uncertain and that definitions in various studies are not always known or transparent. As a result, future research into the use of degraded land needs to focus on these points so that land tenure conflicts and possibly resulting indirect LUC does not occur.

For **Indonesia**, it was found that there are **many, interrelated causes and underlying drivers** that are responsible for this LUC. It is shown that palm oil alone cannot explain the large loss in forest cover but that rather a web of interrelated direct causes (including palm oil production expansion) and underlying drivers are responsible. Important direct causes were found to be logging, palm oil expansion and other agricultural production and forest fires, while underlying drivers were found to be population growth, agriculture and forestry prices, economic growth and policy and institutional factors. In **Malaysia** the most important **causes of LUC vary per region**: In Sabah and Sarawak the most important causes have been **timber extraction and shifting cultivation** while in Peninsular Malaysia, and in recent years increasingly in Sabah, forest cover has been affected most by **conversion to agriculture**, mainly palm oil production. But also underlying drivers such as agricultural and forestry prices, economic growth and policy and institutional factors played a role in LUC in Malaysia.

For each country four projections of future palm oil production were made based on information from different sources and stakeholders of palm oil production. Projections for **Indonesia** show that additional land requirements for future palm oil production expansion range between 5 and 20 Mha for the base case (assuming past yield trends), while the improved case (assuming increased yield trends and a 20% share of immature palms) shows a significant reduction in additional land requirements (now ranging from 1 to 7 Mha). For **Malaysia**, additional land requirements range between 1 and 4.5 Mha for the base case and between no additional land required to an additional 3 Mha for the improved case. This indicates that also in Malaysia a significant reduction in land requirements (even if at a smaller rate than in Indonesia) can be achieved when higher yields are obtained. The main reason for this smaller reduction can be found in that Malaysia currently has a low share of immature palms and that, in order to keep improving yields, it is necessary to increase this share (i.e. increased and/or earlier replanting). As a result, the area of immature oil palms in the improved case increases compared to the base case. In contrast, Indonesia has currently a large share of immature palms but is assumed to decrease in the future.

The palm oil expansion projections are matched with projections on reference land use to determine whether enough land is available for these palm oil expansion projections to be feasible. The projections of reference land use are primarily based on whether deforestation is allowed to occur, on whether this deforested land may be used for palm oil production or other expansion of agriculture, on whether peatland may be used for palm oil production, and on the availability and use of degraded land. The matching of land requirements and land availability shows for Indonesia that very large expansion of palm oil production is possible at the expense of forest cover. But additional forested land and peatland are not necessarily required for most projections of palm oil production expansion to be feasible. This is because yield improvements can largely reduce land requirements while also large amounts of degraded land exist in Indonesia. However, the current use and ownership of degraded land need to be accounted for before expansion on degraded land so that it does not cause indirect LUC, social conflicts and human rights violations. In addition, uncertainties about the actual extent and location of degraded land in Indonesia are high and need to be further investigated. While much less degraded land is available for sustainable palm oil production expansion in Malaysia, also these issues must be accounted for there. In general, the land area available for palm oil production expansion but particularly sustainable expansion potential is more limited in Malaysia, which is due the smaller total land area but also because of the better land management than in Indonesia. As in Indonesia, yield improvements are also an important component of allowing potentially sustainable expansion in Malaysia. It is important to determine national and sub-national strategies with which these yield improvements may be realised. In the short term, Jalani et al. (2002) suggest focussing mainly on applying fertiliser and other inputs more appropriately, practising good harvesting standards and quickly transporting the fruit to the mill. In the long term also proper replanting (with respect to the timing of replanting and replanting with high yielding palms) will be important.

While production on degraded land is favourable in terms of GHG emissions, other sustainability aspects need to be taken into account as well. **Thus, before this expansion takes place on degraded land in either Indonesia or Malaysia, especially the social aspects with respect to the current (degraded) land use and (degraded) land ownership need to be investigated.** Future expansion of palm oil production must not result in social conflicts and especially not in the current users of degraded land to move into undisturbed forest and cause indirect land use change and deforestation.

Large ranges of GHG emissions are associated with future LUC induced by palm oil production in either country, ranging from -40 million to +589 million tonne of CO_2 equivalent per year in **Indonesia** and from -6 million to 24 million tonne of CO_2 equivalent per year in **Malaysia**. The much smaller emissions of Malaysia are caused by the much smaller amounts of land that are projected to be converted to palm oil in Malaysia than in Indonesia. The **large ranges** in projected emissions are caused by the expansion on different land types: when palm oil is produced on former forest covered land or drained peatland large emissions (higher end of ranges) occur, while production on former degraded land shows that overall negative emissions are possible so that palm oil production would become a carbon sink.

12.1 Recommendations

Based on the analysis of this study the following recommendations are made to stimulate sustainable LUC (here primarily focussing on the changes induced by palm oil production expansion) in the future. Recommendations are made for the various actors of palm oil production expansion. Included here are palm oil producers, research groups, the Indonesian government, the Malaysian government and the international community around sustainable palm oil.

Palm oil producers

- *Improve yields*
  This study has demonstrated that yield improvements strongly affect the total land requirements by the Indonesian and Malaysian palm oil sector. In order to realise such improvements, Indonesian palm oil producers, experimental research institute and the governments of Indonesia and Malaysia need to invest into more research on how yields can be improved for the various conditions in Indonesia and Malaysia but particularly for the use of degraded land. The strategies presented by Jalani et al. (2002) serve as a good starting point for yield improvements in both Malaysia and Indonesia. But it must also be noted that yield improvements depend highly on the new planting material and replanting of old plantations. Replanting, and thereby the introduction of higher yielding palms, is generally much slower than other agricultural crops due to the palm oil plantation age of 25 years.

- *Replant properly*
  Proper replanting is an important factor in helping improve yields, while also facilitating harvesting. It was seen the current share of immature palms in Indonesia is very high and that in the future a high share (20%) is projected. But it is important to note that too low of a share will cause yields to develop slower as new planting material with higher yields enters the production much more slowly as was observed to be the case in Malaysia. In the long term, both countries should strive for a share of immature palms of around 20%. Especially for Malaysia this implies that more rapid replanting is required in order to help increasing the yields to the given targets.

- *Improve oil extraction rate*
  Another aspect of improving yields in Indonesia is its relatively low oil extraction rate compared to Malaysia. The oil extraction rate is closely related to management on the plantation as unripe or overripe fruit will lower the oil extraction rate of a mill. Therefore, plantation workers and especially smallholders need to be trained on how to recognise when fruits are ready to be harvested while also transportation of fresh fruit bunches to mills (especially from the more distant smallholders) needs to become faster.

- *Reduce GHG emissions by better management of plantation*
  Various management improvements options such as increasing yields, using degraded land for palm oil production, applying the water from the waste water treatment as irrigation water and "closing" the wastewater treatment so that anaerobic digestion of the wastewater in closed conditions can produce methane, which can then be collected and used for producing electricity need to be implemented can greatly improve the GHG balance of palm oil production as well as its effects on the immediate environment.

- *Investigate potential environmental and social impacts of using degraded land*
  Before planting, a comprehensive environmental and social impact assessment according to RSPO standards and including stakeholder consultations should be conducted in order to investigate land use and ownership claims of degraded land so to avoid land tenure/ownership conflicts with the current users of degraded land but also to avoid causing indirect LUC by forcing the current users of degraded land to move into other areas, possibly forested land.

- *No new plantings on peatland*
  Based on literature findings that peatland used for palm oil production cannot be considered sustainable especially from a GHG emission point of view, new oil palm plantations should not be located on peatland.

Research groups

- *Create more knowledge on degraded land*
  More knowledge on degraded land needs to be generated. This includes knowledge on the level of degradation, location of and developments over time in degraded land, and current status of the land (land ownership/tenure and current use). Especially the ownership and tenure situation must be evaluated before planting oil palm so that it does not cause indirect LUC because previous users of the land were displaced. But also important here is the definition of what degraded land actually is so that the extent of degraded land can be measured more accurately and that potentials for future expansion can be better defined.

- *Create more knowledge on the use degraded land for palm oil production*
  More knowledge is required about the use of degraded land for palm oil production, i.e. preparation and management of degraded land in order to make it an economically interesting option for palm oil producers. This includes also more information on the level of palm oil yields on such land and how the yields can be improved. For Indonesia, particular attention should be placed on smallholders because of their large share in total production and low yields compared to private plantations.

- *Investigate the causes and chronological order of causes*
  Generate more knowledge on the causes and chronological order of causes of LUC to be able to set up better measures and policy with which forest cover loss can be reduced. The most useful analysis is one of satellite images of various years, i.e. remote sensing.

- *Determine forest cover in Malaysia*
  This study found that only little information is available on forest cover in Malaysia. Governmentally assigned forest land, particularly productive PFE and state land forest, has been continuously logged over the past 30 years and some is still being logged today. Based on the knowledge of the negative effects of logging, it is likely that the land demarcated as forests is not necessarily covered by forest. In order to conserve forests and to understand changes in forests, more knowledge on forest cover in Malaysia is needed. This assessment should also include more research into the amount of logged-over forest and its current conditions in Malaysia because this will help determining where forest cover is affected by previous logging.

Indonesian government

- *Reassess forest land classification*
  The classification of forest land needs to be reassessed because there is forested land, which is not classified as forest; there is primary forest, which is categorised as conversion forest; and there is degraded forest, which belongs to conservation or protection forest. For better protection of forests, it is suggested that conversion forest with forest cover, should not be used for conversion purposes but rather it should be reclassified as protection or conservation forest and that degraded forest classified as conservation or protection forest should be identified as such and reforested.

- *Prevent production forest becoming unproductive*
  Related to the reclassification of forest land is the Indonesian government's decision that, if production forest becomes unproductive, part of it can be re-assigned to conversion forest (Kartodihardjo and Supriono, 2000). This change in classification would allow that degraded, former production forest becomes available for clear cut and for conversion to other uses such as palm oil production or timber plantations. This creates a perverse incentive to degrade production forest in order to increase the land area available for forest conversion and thereby improving possibilities for palm oil and timber plantation expansion (Kartodihardjo and Supriono, 2000). These unintended results show that this is not a good policy for the already dwindling forest resources in Indonesia. Instead of turning unproductive production forests into conversion forests, the government should require logging companies to reforest and restore the sites and prevent unproductiveness of production forest in the first place.

- *Demarcate timber and palm oil plantation on degraded land*
  Important for improving the conditions of Indonesian forests is also the allocation of concessions: the amount and location of logging concessions as well as logging techniques need to be scrutinised in order to avoid logging in primary forests and the currently resulting degradation of primary forests while timber plantation and tree crop plantation concessions should not be demarcated on forest covered land or drained peatland even if this land is considered conversion forest. It is suggested that the Indonesian government only hands out concessions for oil palm or any other use such as timber plantations that are located on degraded land, invests into research for preparation and management of degraded land and provide this type of information to palm oil growers. Drained peatland, however, should not be used for palm oil production and timber plantations when it is possible to restore it to its original condition because of peatland's high GHG emissions over a long period of time and because of other biodiversity issues related to the loss of peatland.

- *Increase dissemination of best management practices of palm oil production*
  More research into better management of palm oil plantations and increased dissemination of the results are required. This is especially important for smallholders because they account for 35% of all land under oil palm cultivation in Indonesia but do not usually have financial, labour and time resources to investigate improvement techniques themselves.

- *Implement additional measures to stop deforestation*
  Additional measures need to be implemented to limit illegal logging and illegal conversion of forest land to other uses. For example, if logging companies apply for palm oil or timber plantation concessions but clear cut the forest without establishing respective plantation, more monitoring and stricter prosecution of such behaviour is required. As mentioned above, also land use planning for the legal uses of forest land and forest covered land needs to be re-evaluated (see recommendations *Reassess forest land classification* and *Prevent production forest becoming unproductive* above).

Malaysian government

- *Reassess forest demarcation based on research findings of actual forest cover in Malaysia*
  This study found that forest cover in Malaysia was difficult to assess. If more knowledge on actual forest cover is available, the assigned forest land needs to be reassessed so that the demarcation of forest land can better protect undisturbed forests and can point to where re- or afforestation can have the largest impact. At the same time, better demarcation of forests and non forest land allows also a better demarcation of concessions for timber and palm oil production.

- *Demarcate future concessions of timber and palm oil plantations on non-forested lands and non-peatland*
  Related to the demarcation of forest land is also the demarcation of future concessions for timber and palm oil production. Concession should only be located on degraded land. State land forest, which is currently allowed to be converted to any other use than

forests, should be studied with respect to forest cover. Forested state land forest should be maintained as such, while deforested state land forest should be evaluated for its importance for biodiversity and other ecological function of forests before it is converted to other uses. If high importance for biodiversity and other ecological function is found then the land should be reforested.

- *Disseminate information on best management practices of palm oil production*
  More research into better management of palm oil plantations and increased dissemination of the results are required also in Malaysia. Especially in the financing of such research and the dissemination of the results, the government of Malaysia could play a role. Even though smallholder palm oil producers make up just 11 % (in terms of land area), this information is especially important to them because of their currently low yields.

International community *(such as Dutch government, NGOs, RSPO, etc.)*

- *Extend sustainability certifications to include better management, improving yields and use of degraded land*
  Based on the result that large amounts of degraded land exist and may be available for future expansion of palm oil production, further development of sustainability certification systems (such as RSPO) should include requirements on improved management and the use of degraded land for palm oil production. Moreover, macro-level impacts of palm oil production such as indirect LUC need to be included.

- *Stimulate improved management and yields*
  Besides including improved management as a requirement in sustainability certifications, the international community should stimulate the improvement of management by increasing knowledge dissemination (especially for smallholders, who often have much lower yields than industrial plantations) and stimulate improved yields by investing into research.

- *Set up case studies on degraded land*
  By helping set up and financing case studies on degraded land, the international community interested in sustainable palm oil production can help stimulating improved management and demonstrate that palm oil production on degraded is possible.

- *Implement measures to stop deforestation*
  Besides the national governments also the international community can prevent deforestation through palm oil expansion. Possible options include, for example, the above-mentioned requirement of sustainability certification systems to use only degraded land for palm oil production or a moratorium on palm oil expansion in Indonesia as recently suggested by Greenpeace. But also measures to stop deforestation by other causes and drivers need to be implemented if deforestation is to stop. Examples of other options to reduce deforestation are the REDD (reduced emissions from deforestation and degradation) mechanism or other financial incentives for conserving the natural rainforest of Indonesia.

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15 BIOX'S MOTIVATION FOR FUNDING THIS PROJECT

"BioX is a renewable energy company specialised in energy from liquid biomass, including palm oil. BioX believes that it can only be successful in the long-term, if the biomass chains in which it is working, are sustainable. Consequently, BioX is an active member of the Round Table on Sustainable Palm Oil (RSPO), and committed to only using RSPO certified palm oil in its future power plants. BioX is also active in other initiatives working towards sustainability certification of biomass, e.g. the Cramer Commission (the Netherlands) and its follow-up activities.

At the same time, BioX realises that not all sustainability issues of the palm oil industry can be tackled by certification of individual estates. Macro-issues such as displacement, competition between food and fuel etc. require a broader approach, including sensitive land use planning on a more strategic (government) level. In order to come to a sensible policy on these macro-issues, BioX believes that the current debate shall be less emotional, and be more based on facts and figures. With this study, BioX aims to contribute to the collection of these facts and figures."

Arjen Brinkmann, Sustainability Manager, BioX Group b.v., June 2008

16 APPENDIX

Appendix A: Definitions And Classifications

General Definitions

Forest

FAO FRA 2005 (FAO, 2006a)

- **Forest:** Land spanning more than 0.5 hectares with trees higher than 5 metres and a canopy cover of more than 10 percent, or trees able to reach these thresholds in situ. It does not include land that is predominantly under agricultural or urban land use. Forest is determined both by the presence of trees and the absence of other predominant land uses. The trees should be able to reach a minimum height of 5 metres (m) in situ. Areas under reforestation that have not yet reached but are expected to reach a canopy cover of 10 percent and a tree height of 5 m are included, as are temporarily unstocked areas, resulting from human intervention or natural causes, which are expected to regenerate. Includes: areas with bamboo and palms provided that height and canopy cover criteria are met; forest roads, firebreaks and other small open areas; forest in national parks, nature reserves and other protected areas such as those of specific scientific, historical, cultural or spiritual interest; windbreaks, shelterbelts and corridors of trees with an area of more than 0.5 ha and width of more than 20 m; plantations primarily used for forestry or protective purposes, such as rubber-wood plantations and cork oak stands. Excludes: tree stands in agricultural production systems, for example in fruit plantations and agroforestry systems. The term also excludes trees in urban parks and gardens.
- **Other wooded land**: Land not classified as forest, spanning more than 0.5 ha, with trees higher than 5 m and a canopy cover of 5 tot 10 percent, or trees able to reach these thresholds in situ.
- **Productive plantation:** Forest and other wooded land of introduced species and in some cases native species, established through planting or seeding, mainly for production of wood or non-wood goods.

Variations in Forest definitions

FAO FRA 2000 (FAO, 2001a)

- **Forest** includes natural forests and forest plantations. It is used to refer to land with a tree canopy cover of more than 10 percent and area of more than 0.5 ha. Forests are determined both by the presence of trees and the absence of other predominant land uses. The trees should be able to reach a minimum height of 5 m. Young stands that have not yet but are expected to reach a crown density of 10 percent and tree height of 5 m are included under forest, as are temporarily unstocked areas. The term includes forests used for purposes of production, protection, multiple-use or conservation (i.e. forest in national parks, nature reserves and other protected areas), as well as forest stands on agricultural lands (e.g. windbreaks and shelterbelts of trees with a width of more than 20 m), and rubberwood plantations and cork oak stands. The term specifically excludes stands of trees established primarily for agricultural production, for example fruit tree plantations. It also excludes trees planted in agroforestry systems.

FAO State of the World's Forest 2007

No definition for **forest** is presented. But as the 2005 forest area presented in the *State of the World's Forest 2007* corresponds to the 2005 value in the FRA 2005, it can be assumed that the same definition is applied (see above for the FRA 2005 definition).

FAO State of the World's Forest 2001 (FAO, 2001b)[45]

- **Forest** includes natural forests and forest plantations. The term is used to refer to land with a tree canopy cover of more than 10 percent and area of more than 0.5 ha. Forests are determined both by the presence of trees and the absence of other predominant land uses. The trees should be able to reach a minimum height of 5 m. Young stands that have not yet reached, but are expected to reach, a crown density of 10 percent and tree height of 5 m are included under forest, as are temporarily unstocked areas. The term includes forests used for purposes of production, protection, multiple use or conservation (i.e. forest in national parks, nature reserves and other protected areas), as well as forest stands on agricultural lands (e.g. windbreaks and shelterbelts of trees with a width of more than 20 m) and rubberwood plantations and cork oak stands. The term specifically excludes stands of trees established primarily for agricultural production, for example fruit tree plantations. It also excludes trees planted in agroforestry systems.

FAO State of the World's Forest 1997 (FAO, 1997)[46]

- **Forest** (definition for developing countries)[47]: Ecosystem with a minimum of 10 percent crown cover of trees and/or bamboos, generally associated with wild flora, fauna and natural soil conditions, and not subject to agricultural practices. The term *forest* is further subdivided, according to its origin, into two categories:
  i) *Natural forests:* a subset of forests composed of tree species known to be indigenous to the area; and
  ii) *Plantation forests:* established artificially by afforestation on lands which previously did not carry forest within living memory; or established artificially by reforestation of land which carried forest before, and involving the replacement of the indigenous species by a new and essentially different species or genetic variety.

Agriculture

FAO definitions (FAO, 2005, FAO, 2006a)

- **Arable land**: Land under temporary crops, temporary meadows for mowing or pasture, land under market and kitchen gardens and land temporarily fallow (less than five years).
- **Permanent crops**: Land cultivated with crops that occupy the land for long periods and need not be replanted after each harvest.
- **Permanent pasture**: land used permanently (five years of more) for herbaceous forage crops, either cultivated or growing wild.

Oil Palm

- **Mature:** Oil palms are considered mature from the age of three or four years, the time when oil palms start bearing fruits to be harvested (Corley and Tinker, 2003).
- **Immature:** Oil palms are generally considered immature until the age of three (sometimes four) years, until when they produce no (or very little) fruit/oil (the closer they got to three) (Corley and Tinker, 2003).
- **Damaged:** Oil palms can be damaged by floods, wind, lighting and other environmental factors (personal communication with A. Brinkmann and P. Meekers, BioX Group).

Other Land Categories

Degraded land: Land which due to natural processes or human activity is no longer available to sustain properly an economic function and / or the original ecological function (FAO, 2007a citing ISO, 1996).

[45] The State of the World's Forest 2001 definition of forest is assumed to be also representative of the reports from 2003 and 2005 as the forest data presented in these three reports are the same.
[46] The State of the World's Forest 1997 definition of forest is assumed to be also representative of 1999 as the forest data presented in both reports are the same.
[47] A distinction between developed and developing countries is made because data for the two groups is collected by different organizations: FAO: developing countries; UN-ECE's Trade Division, Timber section: developed countries (FAO, 1997)

Critical land: "Land [so] severely damaged that it has reduced or lost its function beyond a tolerable limit" (Indonesian Ministry of Forestry, 2007).

Grassland: Land with herbaceous types of cover. Tree and shrub cover is less than 10% (Earthtrends, 2007c, technical notes, GLCCD).

Shrubland: Land with woody vegetation less than 2 metres tall and with shrub canopy cover greater than 60% (closed shrubland) or between 10-60% (open shrubland). The shrub foliage can be either evergreen or deciduous (Earthtrends, 2007c, technical notes, GLCCD).

Savannah: Land with herbaceous and other understory systems, and with forest canopy cover between 10-30% (non-woody savannah) or 30-60% (woody savannah). The forest cover height exceeds 2 metres (Earthtrends, 2007c, technical notes, GLCCD).

Wetlands: "An area that is inundated or saturated by water at a frequency and for a duration sufficient to support a prevalence of vegetation typically adapted for life in saturated soil conditions" (International Mire Conservation Group, 2004).

Peatland: Peatland is a type of wetland "with a naturally accumulated layer of peat at the surface" (International Mire Conservation Group, 2004). In this study peatland refers to land with organic soils and originally having forest cover (also called peat swamp forests).

Other Definitions

Deforestation: "The conversion of forest to another land use or the long-term reduction of the tree canopy cover below the minimum 10 percent threshold" (FAO, 2001a)

Definitions Specific to Indonesia

Forest

FWI / GFW (Forest Watch Indonesia and Global Forest Watch, 2002)

- **Conservation Forest:** Forest that is designated for wildlife or habitat protection, usually found within national parks and other protected areas.
- **Conversion Forest:** Forest that is designated (under an IPK license) for clearance and permanent conversion to another form of land use, typically a timber or estate crop plantation.
- **Forest/Forest Cover:** Land on which trees form the dominant vegetation type. The FAO defines forest as land with tree crown cover of more than 10 percent of the ground and land area of more than 0.5 ha. In addition, the trees should characteristically reach a minimum height of 5 m at maturity. It should be noted that a canopy cover threshold of 10 percent represents quite sparse tree cover; most natural forest in Indonesia is closed canopy forest. The Indonesian government uses a land use definition of forest in the various land use classes that comprise "Permanent Forest Status" (*see below*). However, up to 20 percent of Permanent Forest Status land has been deforested.
- **Limited Production Forest:** Forest that is allocated for low-intensity timber production. Typically, limited production forest is found in mountainous areas where steep slopes make logging difficult.
- **Permanent Forest Status:** Land that is legally allocated as part of the national forest estate and falls under the control of the Ministry of Forestry. The term refers to land *use* (land intended for the purposes of forestry) not to land *cover* (land covered with trees). Land under permanent forest status is not necessarily forested and is not therefore the equivalent of forest cover (*see above*).
- **Protection Forest:** Forest that is intended to serve environmental functions, typically to maintain vegetation cover and soil stability on steep slopes and to protect watersheds.
- **Production Forest:** Forest that falls within the boundaries of a timber concession (under an HPH license) and is managed for timber production. Under good management, harvesting levels are balanced by planting and regrowth so that the

forest will continue to produce wood indefinitely. In practice, forests within timber concessions are often heavily logged and sometimes clear-cut.
- **Plantations:** Forest stands established by planting and/ or seeding in the process of afforestation or reforestation. They comprise either introduced species (all planted stands) or intensively managed stands of indigenous species. Plantations may be established to provide wood products (timber, pulp) or such agricultural crops as oil palm and coconut.

Whitten 1987 (based on FAO/World Bank, 1985)
Whitten applies the following categories of forests but gives no definitions. The original source and definitions applied in this source could not be obtained.
- **Protection forest**
- **Parks and reserved** – assumed to be the same as conservation forest in FWI/GFW
- **Production forest**
- **Conversion forest**

Contreras-Hermosilla and Fay 2005(based on Forestry Planning Agency 1999)
Contreras-Hermosilla and Fay apply the following categories of forests but gives no definitions. The original source and definitions applied in this source could not be obtained.
- **Nature reserve/nature conservation/hunting park (KSA/KPA/TB)** - assumed to be the same as conservation forest
- **Protection forest (HL)**
- **Limited production forest (HPT)**
- **Permanently production forest (HP)**
- **Convertible production forest (HPK)** – assumed to be the same as conservation forest in FWI/GFW

Indonesian Ministry of Forestry (Indonesian Ministry of Forestry, 2007)
- **Conservation forest** is a forest area with a specific characteristic with the main function for conservation of animal and plant species and their ecosystem.
- **Protection forest** is a forest are with the main function to protect life support system, maintain hydrological system, prevention of flood, erosion control, prevention of seawater intrusion, and maintain soil fertility.
- **Production forest** is a forest area that is promoted for sustainable forest production. Production forest is classified as *permanent production forest*, *limited production forest* and *convertible production forest*.[48]

Agriculture
BPS Indonesia (Indonesian Bureau of Statistics, 2007)
- **Arable land:** land which includes wetland, dryland/garden/for crop cultivation and temporary fallow land.
- **Estates:** land planted with commercial crops such as rubber, palm oil, coconut, pepper, tobacco, sugar cane, cloves, etc.
- **Meadows:** land usually used to raise livestock.

Definitions Specific to Malaysia

Forest Land
Department of Forestry (Kiam, 2005)
- **Permanent Reserved Forest:** Forested areas that are gazetted as Permanent Reserve Forest that are managed sustainably for the benefit of both present and future generations (Kiam, 2005).
- **Permanent forest estate (PFE)**: "all areas legally designated as reserved forest under the various state forest enactments and, later, under the National Forestry Act (1984) – now the National Forestry (Amendment) Act (1993)" (Kumari, 1995);

[48] No definitions are given for when a production forest is permanent, limited and convertible.

- **National Parks and Wildlife & Bird Sanctuary:** Forested areas designated for the protection of the environment and the conservation of biological diversity (Kiam, 2005). National parks, wildlife sanctuaries and wildlife reserves are "totally protected areas gazetted under the Wildlife Act (1972)" (Kumari, 1995);
- **Stateland Forest:** Forested areas earmarked for future development (Kiam, 2005). State land forest "has been referred to as 'forests that are theoretically targeted for conversion' (World Bank, 1991); 'land for which no long-term use has been decided' (Jaako-Poyry, 1990); or 'land which could over the long term be co-opted into the PFE system or converted to some alternative form of land development, at the discretion of the State authorities' (World Bank, 1991)" (Kumari, 1995).

Sothi Rachagan, 1998
The **PFE** is a term for the sum of forest reserves, areas maintained or managed for their economic, social and ecological benefits. There are four categories within the PFE:

- **Production forest** intended to ensure supply in perpetuity of forest produce, principally timber for domestic purposes and export earning,
- **Protection forest** aimed at sound climatic and physical condition of the country, soil fertility and environmental quality, and minimization of damage by floods and erosion to rivers and agricultural land,
- **Amenity forests** for recreation, and protection of the country's flora and fauna, and
- **Education and Research Forests** – no definition given

Forest Functions

Sabah Forestry Department, 2008b

- Class I: **Protection Forest:** Forest conserved for the protection of watershed and maintenance of the stability of essential climatic and other environmental factors. These areas cannot be logged.
- Class II: **Commercial Forest:** Forest allocated for logging to supply timber and other produce, contributing to the State's economy. Logging is carried out according to Sustainable Forest Management (SFM) principles.
- Class III: **Domestic Forest:** The produce from this forest is for consumption of local communities only and commercial use is discouraged.
- Class IV: **Amenity Forest:** Forest for providing amenity and recreation to local inhabitants. Recreational facilities may be provided in attractive sites, often on roadsides, within these reserves. Exotic tree species are often planted to enhance the amenity value of these areas.
- Class V: **Mangrove Forest:** Forest for supplying mangrove timber and other produce to meet the general trade demands. The Rhizophora sp. is the most commonly harvested, and the products range from firewood to fishing stakes.
- Class VI: **Virgin Jungle Forest:** Forest conserved intact strictly for forestry research purposes. Logging is strictly prohibited in this forest reserve. The Sepilok Virgin Jungle Reserve in Sandakan covers 4,000 hectares and is one of the largest tracts of undisturbed lowland dipterocarp forests in Sabah.
- Class VII: **Wildlife Reserve:** Forest conserved primarily for the protection and research of wildlife. The Sumatran Rhinoceros is one of the endangered wild animals homed in the Wildlife Reserves.

Appendix B: Reference Land Use – Indonesia and Malaysia

Definition: The term "reference land use" refers to the changes in all land use categories except palm oil and thereby determines how much land in each land category may become available for conversion to palm oil production in the future. It includes the following categories: forest (cover), agriculture, degraded land, timber plantations. Besides determining available land, the reference land use systems also refer to the type of land that may be converted to oil palm cultivation. Three different projections of future reference land use are defined and described individually for each land category below.

Forest Cover

1. *Business as usual:* Forest cover declines as in the recent past.
   Indonesia: Extrapolation of past forest cover loss is based on the average annual deforestation rate between 1997 and 2003 (see Table 48). The loss in forest cover amounts to 21 Mha by 2020 compared to the 2003 level. Logging concessions are also found in conversion forests (with approximately one third of all concessions) and it is assumed that all of the conversion forest available in 2003 will be available for conversion until 2020. It is assumed that all deforested land may be used by palm oil production or by any other land use option.
   Malaysia: Extrapolation of past forest cover loss is based on the average annual deforestation rate between 1990 and 2000. The total loss in forest cover amounts to 0.6 Mha by 2020. It is assumed that all deforested land may be used by palm oil production or by any other land use option.

2. *Small improvements*: Forest cover loss continues as in the past but deforested land may not be used for palm oil production.
   Indonesia: Conversion forest with forest cover is expected to be reclassified as forest and is not available for any other use. Conversion forest without forest cover remains available for conversion for palm oil production or any other use.
   Malaysia: Only deforested land from before 2005 maybe used for palm oil production, while deforested land since 2005 may not be used.

3. *Sustainability*: Area with forest cover remains constant.
   Indonesia: For Indonesia this means that in 2020 forest cover amounts to 86 Mha. Forest cover remains constant compared to the 2003 level and no land with forest cover is available for oil palm expansion. Conversion forest (with or without forest cover) is not available for conversion and conversion forest with low forest cover is assumed to be reforested.
   Malaysia: In 2020 forest cover amounts to 19.5 Mha. Forest cover remains constant compared to the 2005 level and land with forest cover is not available for oil palm expansion.

Agricultural land

1. *Business as usual; 2. Small improvements*: Extrapolation of past agricultural land changes (excluding land under oil palm cultivation) are made on the basis of FAO data on arable land, permanent cropland and permanent pastures from 2000 to 2005 (FAOSTAT, 2007).
   Indonesia: The total agricultural area (without palm oil) will increase from 44.1 Mha to 50.5 Mha in 2020. The additional land requirements from agriculture are taken from deforested land.
   Malaysia: The total agricultural area (without palm oil) decreases to 3.1 Mha in 2020, which frees 0.6 Mha of land for other uses.

3. Sustainability: Agricultural land develops according to projections made for yields, population growth and diets by FAO projections for the study "World Agriculture: towards 2015/2030" and additional requirements for land from agriculture will be taken from degraded land. Agricultural food production may also not be displaced by any other type of land use. Since the FAO projections of the study "World agriculture: towards 2015/2030" are based on larger regions, it is assumed that **Indonesia**'s agricultural land (without oil palm) increases at the same rate as it does for South Asia (excluding China). Because the FAO only makes projections for arable land, it is assumed that permanent cropland without palm oil in Indonesia increases at the same rate as arable land and that pastures remain constant as these have hardly changed in the past and future meat production is likely to become more intensified so that even less pasture land may be required. The growth rate of arable land in South Asia from 1998 until 2030 is determined to be 0.43 % per year (FAO, 2003), which causes the agricultural land (without oil palm) in Indonesia to increase from 44.1 Mha in 2005 to 46.3 Mha in 2020.

Malaysia: Expansion of Malaysia's arable land is assumed to increase at the same rate as it does for South Asia (excluding China), while permanent crop (without palm oil) is kept constant at the 2005 level assuming no additional land under rubber or coconut cultivation is converted. Also the permanent pasture area is kept constant as it has hardly changed in the past. As a result, Malaysia's agricultural land without palm oil increases from 3.7 Mha in 2005 to 3.8 Mha in 2020.

Degraded land

1. *Business as usual; 2. Small improvements; 3. Sustainability:* Remains constant

Indonesia: In all projections, degraded land is assumed to remain constant compared to the 1998 level, 12.5 Mha (Casson, 2000), as no information regarding its development can be found in literature – other than that it is likely to increase.[49] All degraded land is available for any developments in agriculture, timber plantation and tree crops including palm oil. But as it is not as economically attractive as forest land (due to the initial income from timber extraction), it is not the first choice of land for palm oil and timber plantation developers.

Malaysia: Degraded land is assumed to remain constant as no information is available on past developments. For future projections, degraded land accounts for both degraded land and *Imperata* grassland and amounts to 1.3 Mha. All degraded land is available for any developments in agriculture, timber plantation and tree crops including palm oil. But as it is not as economically attractive as forest land (due to the initial income from timber extraction), it is not the first choice of land for palm oil and timber plantation developers.

Timber Plantations

1. *Business as usual; 2. Small improvements; 3. Sustainability:* Timber plantation expansion continues as in the past.

Indonesia: Timber plantations increases according to the past trend and amount to 5 Mha in 2020.

Malaysia: Timber plantations increases according to the past trend and amount to 0.44 Mha in 2020.

Peatland

1. *Business as usual; 2. Small Improvements*: Peatland may be deforested and used for any other land use.

Indonesia: Based on the study of Hooijer et al. (Hooijer et al., 2006), it is assumed that 27% of all palm oil production area is located on peat.

Malaysia: It is assumed that 13% of all forest land used for palm oil production is peatland, which is based on the forest cover in 1966 amounting to 22.4 Mha (ABC and WCMC, 1997) and original peatland amounting to 2.7 Mha (Rieley and Page, 2005). It is assumed that 11% of all other agricultural land converted to palm oil

[49] Indonesian MOF data is not included in the reference degraded land because the Indonesian government has designated the critical land to be rehabilitated again so that this land would not be considered degraded anymore in the future. Moreover, the large differences in data (2000 vs. 2004 and compared to other sources – see section 3.6) and the lack of knowledge on how land is determined to be critical explain why this dataset is not applied here. WWF suggests that degraded land amounts to even 18 Mha in Indonesia. But as these figures could not be traced to its source and the assumptions it is based on, this number is not included.

production is peatland, which is based on 0.9 Mha peatland being used for agriculture according to Jamaludin (2002) and a total of 7.9 Mha agricultural land (Table 32).

3. *Sustainability*: **Indonesia and Malaysia:** No peatland is deforested and used for palm oil.

Palm oil

1. *Business as usual*:
   Indonesia: Palm oil may be expanded on deforested land, all conversion forest and peatland. Degraded land is used sometimes but is only done when no other land is available. Agricultural land may be displaced.
   Malaysia: Palm oil is produced primarily on land that was previously used for rubber and coconut plantations. Additional land requirements are met with logged over forest.

2. *Small improvements*:
   Indonesia: Palm oil may be expanded on only that part of conversion forest which is not covered by forests (forested conversion forest is assumed to be reclassified as forest), including peatland. Deforested land is not used for palm oil production. Degraded land is used sometimes but is only done when no other land is available. Agricultural land may be displaced.
   Malaysia: Palm oil is produced primarily on land that was previously used for rubber and coconut plantations. Deforested land is not used for palm oil production. Degraded land is used sometimes but is only done if no other land is available.

3. *Sustainability:*
   Indonesia: Palm oil may not be expanded on peatland and deforested land. Conversion forest (both with and without forest cover) is not allowed to be used. It is assumed that not-forested conversion forest is reforested and conversion forest is reclassified as forest. Agricultural land may not be displaced. Palm oil may be produced only on degraded land, which is not needed for food production.
   Malaysia: Palm oil may not be expanded on peatland and deforested land. Agricultural land may not be displaced. Palm oil may be produced only on degraded land, which is not needed for food production.

Appendix C: Detailed Description of Land Use Data - Indonesia

Forest land

Whitten 1987

In his study on Indonesia's transmigration programme and its role in tropical rain forest loss, Whitten presents data from FAO/World Bank from 1985 for different forest types on a provincial level for Indonesia in **1984** (Whitten, 1987). These categories are protection forest, parks and reserved forest, production forest and conversion forest (Whitten, 1987). The underlying data as well as the definitions applied could not be traced. Data are presented in Table 3.

Forest Watch Indonesia and Global Forest Watch, 2002

Forest Watch Indonesia and Global Forest Watch (FWI/GFW) present data on the permanent forest status[50] for **1986** and **2000** in "The State of the Forest: Indonesia" study from 2002 (Forest Watch Indonesia and Global Forest Watch, 2002). The data originates from different Indonesian government sources but for both years the same forest classifications are applied as in the FAO/World Bank study cited in Whitten (1987) – the definitions used by FWI/GFW are presented in the Appendix A. For 1986, FWI/GFW cites data from the Ministry of Forestry, while the 2000 data is based on the Indonesian Regional Physical Planning Programme for Transmigration (RePPProT). Data is presented in Table 3.

Indonesian Ministry of Forestry - Land Use by Consensus (TGHK)

According to Santoso (2003), the initial need to delineate forest zones originated from various business and conservation interests such as where logging concessions could be located without displacing agricultural activity. The delineation process was performed by the department of *Forest land Use By Consensus* (TGHK) and focussed on the function of forest rather than land cover. The resulting map refers to the status of forest in **1994**, the applied forest land categories are the same as those in Whitten (1987) but no definitions of these categories are given in the studies and original sources could not be obtained.[51] The amount of land under each forest type in 1994 is shown in Contreras-Hermosilla and Fay (2005) and in Santoso (2003) and is presented here in Table 3.

RTRWP and Harmonisation

The TGHK forest zones resulted in large differences of opinion, despite its assignment for defining forest use by consensus (Contreras-Hermosilla and Fay, 2005). A compromise was developed from 1999 to 2001 through the *Provincial Level of Spatial Planning Process* (RTRWP) and the result of this harmonisation process, the forest land area in **1999**, is presented in Table 3.

Indonesian Ministry of Forestry – Statistics 2003

The Indonesian Ministry of Forestry (MOF) presents forest land statistics for **2003** (Indonesian Ministry of Forestry, 2007), which uses the same classification as in the previous studies. The applied definitions are presented in Appendix A. While definitions vary slightly in wording, the definitions are comparable to those applied by GFW/FWI. The land in each forest classification is presented in Table 3.

Forest cover

Data from Indonesian Ministries

Data on forest cover in Indonesia was presented in Table 47 for 2003. Similar data on forest cover for other years could not be obtained from the Indonesian ministries.[52]

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[50] Land that is legally allocated as part of the national forest estate and falls under the Ministry of Forestry (Forest Watch Indonesia and Global Forest Watch, 2002).

[51] The actual map that was produced in the delineation process could not be obtained.

[52] While the MOF does present forest cover for various years (2001-2005) all of them are the same and based on remote sensing analysis for 2002/2003.

Table 47: National forest cover in 2003 for different forest categories

Forest land category	Total forest land*	Forest cover**		Non forest cover		No data	
	1000 ha	1000 ha	%	1000 ha	%	1000 ha	%
protection forest	30052	22102	74	5622	19	2328	8
parks and reserved forest	19876	14365	72	4009	20	1502	8
production forest (regular and limited production)	60915	38804	64	18404	30	3706	6
regular production	35258	20624	58	12639	36	1995	6
limited production	25656	18180	71	5765	22	1711	7
conversion forest	22732	10693	47	11057	49	981	4
Total forest	**133575**	**85964**	**64**	**39092**	**29**	**8517**	**6**

Source: Indonesian Ministry of Forestry, 2007: Table I.1.2
* The total forest land is the same as the 2003 entry in Table 3
** The total forest cover is the same as stated in Table 48 for 2003

Data from FWI/GFW

According to data retrieved from FWI/GFW (2002, citing Hannibal, 1950 RePPProT, undated and Holmes, 2000), forest cover decreased from 162 Mha in 1950 to 117 Mha in 1985 to 96 Mha in 1997 (Table 48, Figure 3). Thus, in 1950 forest cover was found on 85% of Indonesian land, while this percentage diminished to 62%, and 50% in 1985 and 1997, respectively.

Table 48: Developments in forest cover on subnational level

Region	1950	1985	1997	2003
Sumatra (1000 ha)	37,370	23,324	16,430	13,517
Kalimantan (1000 ha)	51,400	39,986	29,637	25,445
Sulawesi (1000 ha)	17,050	11,269	7,951	7,845
Irian Jaya (Papua) (1000 ha)	40,700	34,958	33,382	31,732
Other Indonesia* (1000 ha)	15,770	10,163	8,228	7,425
Total Indonesia (1000 ha)	**162,290**	**119,700**	**95,629**	**85,964**
Forest cover percentage (%)	**85**	**63**	**50**	**45**

Source: **1950**: Forest Watch Indonesia and Global Forest Watch, 2002 citing Hannibal, 1950
1985: Forest Watch Indonesia and Global Forest Watch, 2002 citing RePPProT[53]
1997: Forest Watch Indonesia and Global Forest Watch, 2002 - GFW estimates based on digital dataset from Ministry of Forestry, Government of Indonesia and the World Bank (2000)[54]
2003: Indonesian Ministry of Forestry, 2007
* Figures stated exclude East Timor, which become independent from Indonesia in 2002.

FAO

Table 49: Overview of forest and other wooded land by FAO Global Forest Assessment

	Forest cover		
	1990	**2000**	**2005**
Total Indonesia (1000 ha)	**116,567**	**97,852**	**88,495**
Forest cover percentage (%)	61	51	46

Source: FAO, 2006a

Stibig and Malingreau 2003

Stibig and Malingreau (2003) show the location of forest cover loss between 1980 and 2000 for Sumatra, Java and Kalimantan (Figure 32) and the amount of land covered by forests (Table 50).

Table 50: Deforestation rates determined by Stibig and Malingreau 2006

	Approx. 1985	2000
Region	1000 ha	
Sumatra	23045	15616
Borneo	53009	39792

[53] Another dataset for 1985 exists that is based on GFW estimates from UNEP-WCMC, "Tropical Moist Forest and Protected Areas: The Digital Files. Version 1." Data vary slightly and cause the overall percentage of forest cover in 1985 to decrease by 1 percent point to 62%. Because of the very small difference the data is not shown here, instead it is referred to Forest Watch Indonesia and Global Forest Watch, 2002 (p. 13).

[54] Another dataset for 1997 exists that is based on the work of Holmes (2000) for the World Bank. Holmes did not live to provide final data for Java, Bali and Nusa Tengara, which is why this dataset is not presented here (see Forest Watch Indonesia and Global Forest Watch, 2002 (p.12)).

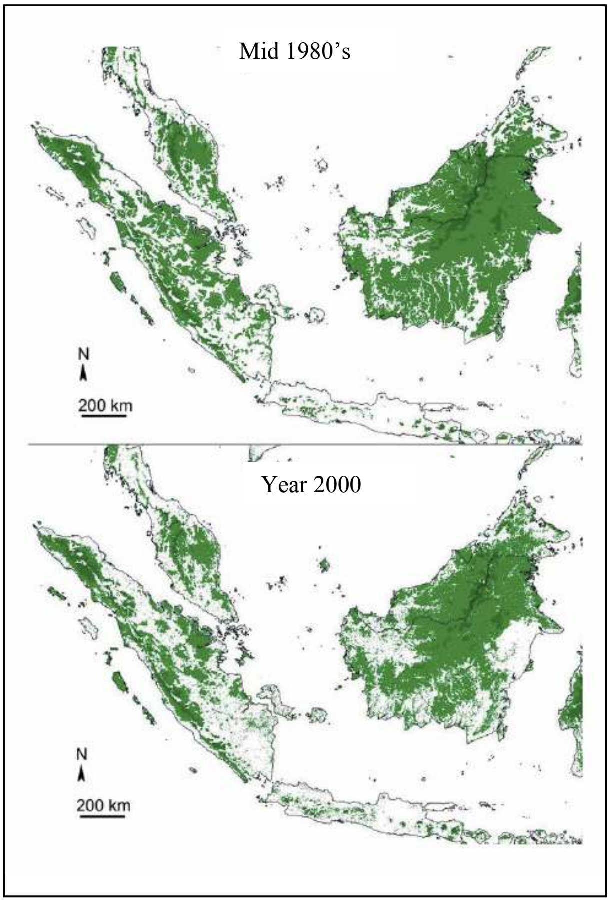

Figure 32: Developments in forest cover in Insular Southeast Asia
Source: Stibig and Malingreau, 2003

Deforestation

FAO Global Forest Assessment

According to FAO data, Indonesian forest cover declined on average 1.7% per year in the period of 1990 to 2000 and 2% per year between 2000 and 2005 (Table 52) (FAO, 2006a). In absolute terms, on average 1.9 Mha were lost each year in the period from 1990 to 2005, showing a rather constant deforestation in terms of land area (Table 52).

Hooijer et al. (2006)

Hooijer et al. (2006), based on GFW 1985 and GLC 2000 data, found deforestation rates between 1985 and 2000 that amount to an average 0.7% per year for Indonesia (Table 53).

Table 51: Developments in deforestation rates (annual averages) on subnational level

Year	**1950-1985**		**1985-1997**		**1997-2003**	
	1000 ha/y	%/y	1000 ha/y	%/y	1000 ha/y	%/y
Sumatra	-412	-1.4	-542	-2.7	-486	-3.2
Kalimantan	-336	-0.7	-834	-2.4	-699	-2.5
Sulawesi	-167	-1.2	-270	-2.8	-18	-0.2
Irian Jaya (Papua)	-157	-0.4	-151	-0.4	-275	-0.8
Other Indonesia*	-216	-1.8	1	+0.01	-134	-1.7
Total Indonesia	**-1289**	**-0.9**	**-1797**	**-1.7**	**-1611**	**-1.8**

Source: calculated from Table 48, which is based on Forest Watch Indonesia and Global Forest Watch, 2002 and Indonesian Ministry of Forestry, 2007
* Figures stated exclude East Timor, which become independent from Indonesia in 2002.
Note that the deforestation data are determined from several and possibly inconsistent sources so that the deforestation rates must be used carefully.

Table 52: Deforestation rates by FAO Global Forest Assessment

	Deforestation rates			
	1990 - 2000		**2000 - 2005**	
	1000 ha/y	%/y	1000 ha/y	%/y
Total Indonesia	**-1872**	**-1.7**	**-1871**	**-2.0**

Source: FAO, 2006a

Table 53: Deforestation rates determined by Hooijer et al. 2006

	1985-2000
Region	%/y
Sumatra	-1.0
Kalimantan	-1.2
Sulawesi	-
Irian Jaya (Papua)	-0.3
Other Indonesia*	-
Total Indonesia	**-0.7**

Stibig and Malingreau 2003

Stibig and Malingreau (2003) determined annual average deforestation rates for Sumatra and Borneo that amount to -2.6 and -1.9%, respectively (Table 54). It must be noted that the 1985 data is referred to as middle of 1980's in Stibig and Malingreau (2003) and that 1985 is assumed here in order to determine annual average deforestation rates. However, if the map was generated a year earlier or later, then deforestation rates would be slightly lower or higher, respectively.

Table 54: Deforestation rates determined by Stibig and Malingreau 2006

	1985-2000	1985-2000
Region	1000 ha/y	%/y
Sumatra	-495	-2.6
Borneo	-881	-1.9

Indonesian Ministry of Forestry

The Indonesian Ministry of Forestry presents a map of the location of deforestation in Indonesia between 1985 and 1998 (Figure 33) on which it can be seen that Sumatra and Kalimantan have been affected most.

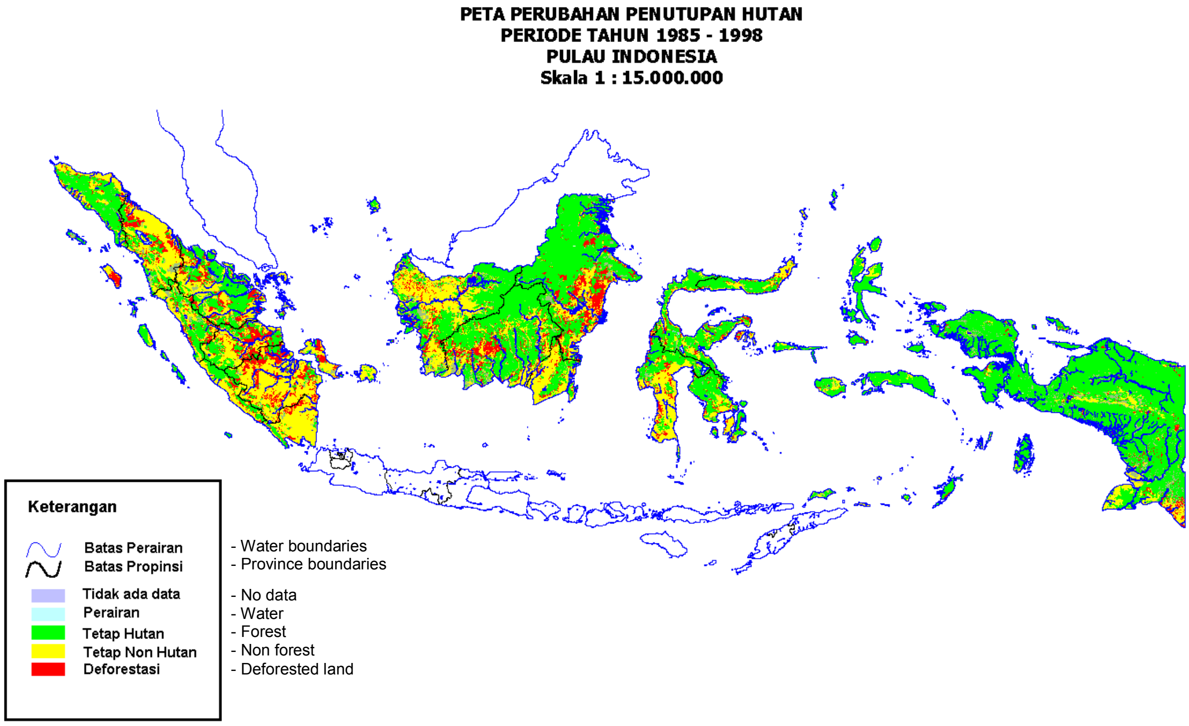

Figure 33: Deforestation in Indonesia 1985 - 1998

Source: Indonesian Ministry of Forestry, 2007

Timber plantations

FAO Tropical Plantation Areas 1997

Data from the report "Tropical Plantation Areas" (FAO, 2002b), presented in Table 5, shows that timber plantations amounted to 8.8 Mha in 1986 and decreased until 1994 to 5 Mha, a decrease by 6.8% per year.

FAO Global Planted Forests Thematic Study

FAO data from the Global Planted Forests Thematic Study (FAO, 2006b) presents a different picture than FAO data from the tropical plantation areas study from 2002: total timber plantations amount to 3.4 Mha in 2005, having increased by 2.5% per year on average between 2000 and 2005 and 3.1% per year on average between 1990 and 2000 (Table 5).

Indonesian Ministry of Forestry

Indonesian forest statistics (Indonesian Ministry of Forestry, 2007) provide information regarding the annual increases of timber plantations from 2000 to 2004 (Table 55) but no information on the total area in 1999 or 2000 was found. Therefore, the area of timber plantations in 1999 is determined from FAO timber plantation area in 1990 and the average growth rate for 1990 to 2000 and used in order to determine the annual growth rates (based on the absolute increases presented by MOF) for 2000 until 2004 (Table 55). Based on the calculated growth rates the total area of plantation in 2004 would add up to 3.44 Mha, which is already slightly larger than the area determined by FAO for 2005. Interesting to note also is that the highest growth rate for the different regions is found for Sumatra, where in 2004 more than 80% of all new plantations were developed Table 55.

Degraded land

GLASOD Data

The Global Assessment of Human Induced Soil Degradation (GLASOD) by the International Soil Reference and Information Centre (ISRIC) from 1990 is used to estimate the degraded land in Indonesia. GLASOD is based on expert opinions from the 1980s and despite the fact that the data is so old, this is currently the only available global database on degraded land with which data for different countries can be compared (Oldeman et al., 1990). GLASOD divides degradation into the level of severity and the frequency of degradation for each level of severity in order to determine the overall amount of land that is degraded (Oldeman et al., 1990). Table 56 present the results for Indonesia: In total a land area of 31.4 Mha is affected by degradation of which 7.5 Mha are dominantly very severely degraded.

Table 55: Annual increases in timber plantations in Indonesia 2000 - 2004

	2000	2001	2002	2003	2004
Sumatra (1000 ha)	54.9	51.1	80.0	110.7	107.8
Kalimantan (1000 ha)	24.5	15.4	23.8	11.7	9.6
Sulawesi (1000 ha)	1.7	0.9	11.3	0.4	1.7
Papua (1000 ha)	0	0	0	0	0
Rest (1000 ha)	1.2	0.2	3.4	1.8	12.9
Total (1000 ha)	**82.3**	**67.5**	**118.5**	**124.5**	**131.9**
Percentage change (%)*	**2.7**	**2.2**	**3.8**	**3.8**	**3.9**

Source: Indonesian Ministry of Forestry, 2007

* Note that, in order to calculated annual growth rates, the starting point is taken as the area of plantations in 1999, which is determined from FAO timber plantation in 1990 and the average growth rate for 1990 to 2000.

Table 56: Land degradation in Indonesia based on GLASOD

Frequency / **Severity**	Infrequent	Common	Frequent	Very frequent	Dominant	**Total Degraded**	**Percentage of total land**
				1000 ha			%
None	-	-	-	-	-	-	0
Light	959	2018	-	-	-	2976	1.6
Moderate	-	1006	6022	-	-	7028	3.7
Severe	-	177	5699	7064	947	13888	7.3
Very severe	-	-	-	-	7479	7479	3.9
Total	959	3201	11721	7064	8427	31371	16.5

Source: FAO, 2008

Casson 2000

Casson (2000) found for Indonesia that large amounts of land are degraded, approximately 12 Mha (Figure 34). However, no information on the definition of degraded land as applied in the Cason study is available, the source data could not be obtained and the exact amounts of degraded land are also not available. However, the figure is presented here in order to get an idea of the location of degraded land. The provinces with the largest amounts of degraded land are (in order of magnitude) East Nusa Tenggara, Central Kalimantan, South Sumatra, South Sulawesi and North Sumatra.

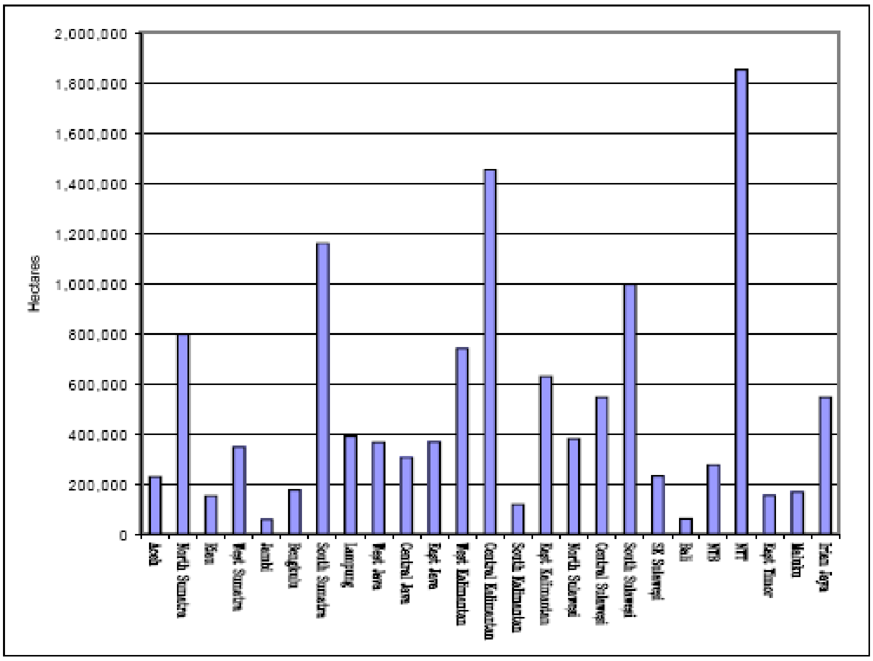

Figure 34: Available degraded land in 1998
Source: Casson, 2000 citing: Departemen Kehutanan dan Perkebunan, 1998. *Eksekutif Data dan Informasi Kehutanan dan Perkebunan, Biro Perencanaan*, Sekretariat Jenderal, Departement Kehutanan dan Perkebunan.

Based on forest land, agricultural land and the total land area of Indonesia, it is clear that degraded land must overlap with forest and agricultural land. However, the extent to which degraded land overlaps with one, the other or both is not known.

Indonesian Ministry of Forestry
The Indonesian Ministry of Forestry applies the term "critical land" (lahan kritis) for land which is so severely damaged that it has reduced or lost its function beyond a tolerable limit (see Appendix A) (Indonesian Ministry of Forestry, 2007). MOF estimates the critical and very critical land area to be 8.1 million and 15.1 Mha in 2000, respectively.[55] In year 2004, very critical land increased to 13.5 Mha, critical land to 20.1 Mha and an additional category of slight critical is added which amounts to 40.4 Mha (Indonesian Ministry of Forestry, 2007). In total, 74 Mha are considered critical land in Indonesia in 2004, which represents 39% of the total land (Indonesian Ministry of Forestry, 2007). It is unclear whether this large increase in critical land between 2000 and 2004 was due to definition changes, different data collection systems or any other reason.

WWF
WWF estimates that 18 Mha are degraded in Indonesia (personal communication with A. Harrison, WWF Scotland, see
Appendix H). While this figure has been used frequently by WWF, it is not clear anymore where this figure originates and on what assumptions and data it is based (personal communication with A. Harrison, WWF Scotland, see
Appendix H). Therefore this data source will not be considered further.

[55] No definitions are presented for the distinction between slight critical, critical and very critical land.

Appendix D: Palm Oil Production Data - Indonesia

Table 57: Palm oil production, area harvested and yields over time (various sources)

	Production				Area				Yields			
	Casson	**BPS**	**IPOC**	**FAO**	**Casson**	**BPS**	**IPOC**	**FAO**	**Casson**	**BPS**	**IPOC**	**FAO**
					Total area	**Unclear**	**Area harvested**	**Area harvested**				
Year	1000 tonne				1000 ha				tonne / ha.yr			
1975	397			397	189			142				2.8
1976	431			431	211			130				3.3
1977	458			458	220			140				3.3
1978	501			501	250			180				2.8
1979	641			641	261			200				3.2
1980	721			721	295			204				3.5
1981	800			800	319			230				3.5
1982	887			887	330			240				3.7
1983	983			983	406			255				3.9
1984	1147			1147	512			296				3.9
1985	1243			1243	597			349				3.6
1986	1351			1351	607			374				3.6
1987	1506			1506	729			422				3.6
1988	1713			1713	863			535				3.2
1989	1965			1965	974			590				3.3
1990	2413			2413	1127			673				3.6
1991	2658			2658	1311			772				3.4
1992	3266			3266	1467			875				3.7
1993	3421			3421	1613			921				3.7
1994	4008			4008	1804			1045				3.8
1995	4350	2476		4480	2025	992		1190		2.5		3.8
1996	4750	2570		4899	2250	1146		1428		2.2		3.4
1997	5380	4166		5385	2516	2109		1623		2.0		3.3
1998	5006	4586		5902	2780	2670		1795		1.7		3.3
1999	5659	4908	6456	6011	2957	2860	2397	1847		1.7	2.7	3.3
2000		5095	7001	6855		2991	2518	2014		1.7	2.8	3.4
2001		5598	8396	7775		3152	2956	2200		1.8	2.8	3.5
2002		6196	9622	9370		3259	3307	2790		1.9	2.9	3.4
2003		6924	10441	10530		3429	3429	3040		2.0	3.0	3.5
2004		8479	12225	12080		3496	3733	3320		2.4	3.3	3.6
2005		10191	13112	14070		3592	3906	3690		2.8	3.4	3.8
2006		10869		15900		3683		4120		3.0		3.9

Appendix E: Details on Colchester Palm Oil Projections - Indonesia

The Colchester projections are based on data that was collected from "all the figures available on provincial land use plans, published in newspapers and various other sources" (Colchester et al., 2006). The amount and location of the projected expansion are presented in Figure 35 and Figure 36.

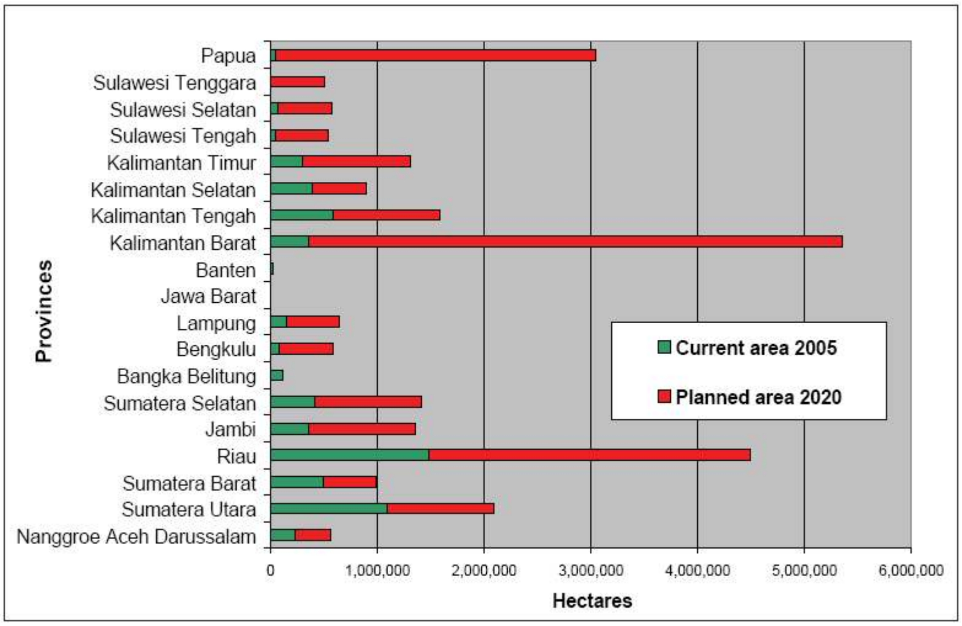

Figure 35: Colchester projection: Oil palm estates: current and projected
Source: Colchester et al., 2006

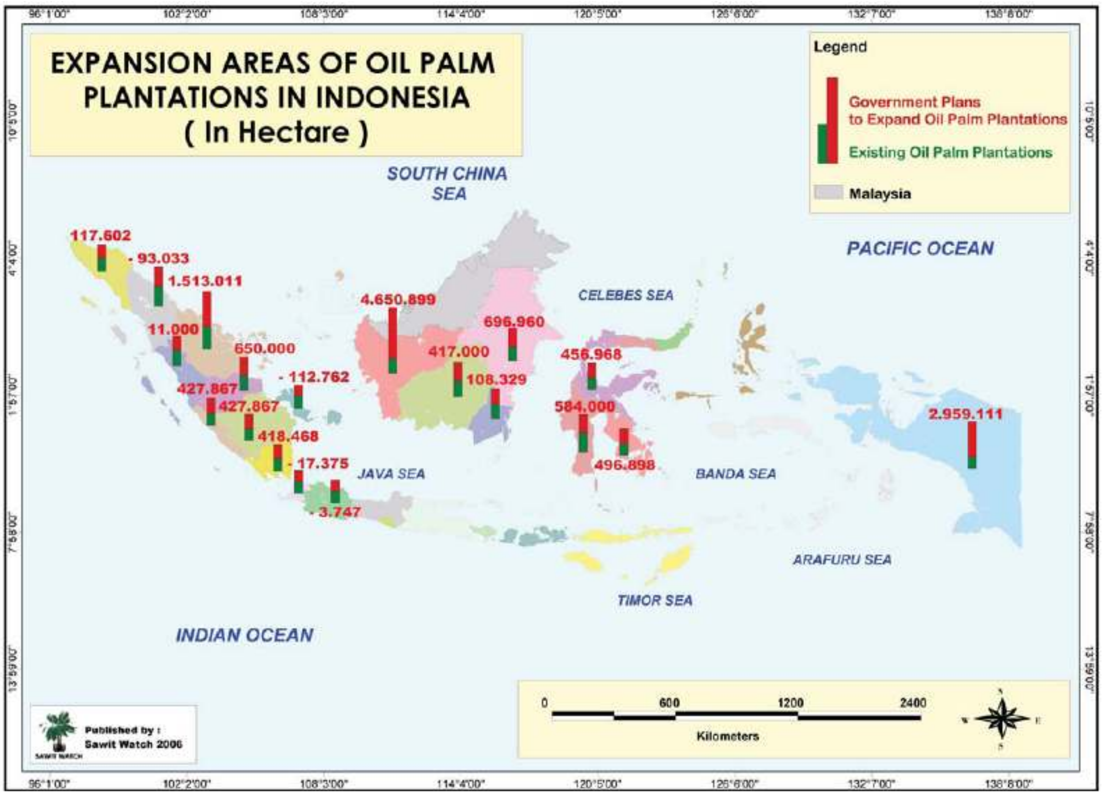

Figure 36: Colchester projection: Expansion areas of palm oil plantations in Indonesia (in hectare)
Source: Colchester et al., 2006

Appendix F: Details on IPOC Palm Oil Projections - Indonesia

IPOC states that "the Indonesian government plans to enlarge its oil palm plantation under the Plantation Revitalisation Program", under which palm oil plantations are extended by 1.375 Mha of land (Table 58) and 125 thousand hectare will be replanted (Table 59).

Table 58: IPOC: Land allocation for revitalisation program for expansion by the year 2010

No	Province	Area (Ha)
1	Nangroe Aceh Darussalam	40,000
2	North Sumatera	10,400
3	West Sumatera	15,200
4	Riau	12,400
5	Riau Islands	21,000
6	Jambi	200,000
7	South Sumatera	117,000
8	Bangka Belitung	5,500
9	Bengkulu	8,200
10	Lampung	2,000
11	West Kalimantan	302,410
12	Central Kalimantan	147,500
13	South Kalimantan	77,996
14	East Kalimantan	301,194
15	Central Sulawesi	1,800
16	South Sulawesi	12,200
17	West Sulawesi	10,000
18	South East Sulawesi	7,200
19	Papua	58,000
20	West Irian Jaya	25,000
		1,375,000

Source: IPOC, 2007

Table 59: IPOC: Land allocation for revitalisation program for replanting by the year 2010

No	Provinces	Total replanting (ha)
1	Nangroe Aceh Darussalam	4,775
2	North Sumatera	29,930
3	West Sumatera	4,850
4	Riau	29,675
5	Jambi	6,000
6	South Sumatera	13,428
7	Bengkulu	2,032
8	Banten	6,364
9	West Kalimantan	10,670
10	East Kalimantan	8,262
11	South Sulawesi	4,200
12	Papua	1,914
13	West Irian Jaya	2,900
	Total	**125,000**

Source: IPOC, 2007

Appendix G: Detailed Description of Land Use Data - Malaysia

Forest cover

FAO Forest Resources Assessment 2005 (FRA 2005)

Forest cover in Malaysia according to FAO FRA 2005 (FAO, 2006a) amounts to 22.3 Mha in 1990, 21.6 Mha in 2000 and 20.9 Mha in 2005. These values are larger than the governmentally assigned forest land. An analysis of the Malaysia country report for the FAO FRA 2005 (Kiam, 2005) reveals that the FAO FRA 2005 data includes rubber plantations in the forest cover data, giving one explanation for the large extent of forests compared to other sources. Moreover, the FRA 2005 data on Malaysia is based on the legally assigned forest land PFE, state land forest and national and wildlife reserves (Kiam, 2005), of which especially productive PFE and state land forest are subject to logging and foraging of other forest products. This can cause degradation of forest and forest cover loss. This indicates that forest cover in Malaysia according to FRA 2005 does not actually portray forest cover but rather forest land.

FAO Forest Resources Assessment 2000 (FRA 2000)

The FRA 2000 report presents forest cover in Malaysia to be 21.6 Mha in 1990 and 19.3 Mha in 2000, both data points are lower than those presented in FRA 2005. It is unclear what the exact causes of these differences in forest cover data for Malaysia are but the FRA 2005 reports presents two reasons for why forest cover estimates for 1990 and 2000 are different in FRA 2005 and FRA 2000 in general:

> "First, the estimates presented in both assessments are derived primarily through linear interpolation and extrapolation of the results from two or more recent assessments. National forest resources assessments are fairly expensive, thus they are often carried out at infrequent intervals and a new dataset can significantly change previous forecasts based, for example, on estimates from the 1970s or 1980s. Second, many more countries were actively involved in the FRA 2005 process than in previous assessments, and the national correspondents helped provide access to better and more recent information, while their detailed knowledge of forest types helped improve the reclassification of data into FRA 2005 categories" (FRA 2005).

FAO State of the World's Forest Reports 1997-2007

Various *State of the World's Forest* reports present the same data as the FRA reports. Thus, the State of the World's Forest 2007 (FAO, 2007b) presents the same value for 2005 as in FRA 2005, while the State of the World's Forest 2001, 2003 and 2005 present the same value for 2000 as FRA 2000 (FAO, 2001b). However, the State of the World's Forest reports of 1997 and 1999 present divergent numbers for 1990 than the 1990 values from FRA 2005 and FRA 2000, which are much lower. According to these two reports, in 1990 forest cover amounted to 17.5 Mha and decreased to 15.5 Mha in 1995 (FAO, 1997).

UNEP, 1997

The UNEP data on forest cover in Malaysia in 1992/1993 is based on the digital AVHRR data and shows that forest cover is 15.9 Mha. But the UNEP data does not have data for 20% of the land area. If assuming the same distribution of forest, croplands and water bodies as in the other 80%, then the total forest area would be 19 Mha.

Stibig and Malingreau, 2003

Stibig and Malingreau (2003) determine forest cover for Malaysia based on a subregional forest map (Figure 32) to be 18.3 Mha in 2000. Stibig and Malingreau (2003) compare this to the 2000 value presented in FRA 2000 and explain the 1 Mha difference by differences in reference years (2000 for subregional map and 1995/1997 for FAO statistics) and by the impact of 1997/1998 fires that occurred (Stibig and Malingreau, 2003).

FAO Forestry Department, 2002
Forest cover data is presented for Malaysia by region: In 2001, Peninsular Malaysia had 5.9 Mha natural forest, Sabah had 4.1 Mha and Sarawak had 9.8 Mha, which together gives a total natural forest cover of 19.8 Mha. No information on the applied definition and the source of this data is presented.

GLCCD
Another source presenting forest cover is the GLCCD database, which suggests that 21.9 Mha of land are covered by forests in Malaysia in 1992 (Earthtrends, 2007c). However, as explained in section 3.5, the GLCCD results are highly uncertain. It is unclear whether the larger forest cover extent according to GLCCD compared to other sources is really due to this uncertainty or due to other factors.

Regional Forest Cover
Table 60 presents an overview of regional forest cover data that was collected from many sources. The different sources have presented different amounts of forest cover in the three Malaysian regions. These differences may be due to the differences in definitions applied. Especially data from recent years for Sabah and Sarawak (2001, 2003 and 2005) show very different outcomes and it is unclear what the cause of this is.

Table 60: Developments in regional forest cover in Malaysia

	1953	1957	1966	1974	1981	1984	1985	1995	2000	2001	2003	2005
	1000 ha											
Peninsular	-	11284	7860	7240	-	6500	-	-	5913	5900	-	5880
Sabah	6331	-	6050	-	5006	4638	4605	-	-	4100	4350	4400
Sarawak	-	-	8554	-	-	-	-	8500	-	9810	8096	9240
Malaysia	**-**	**-**	**22464**	**-**	**-**	**-**	-	**-**	**-**	**19810**	**-**	**19520**

Sources: **1953:** Sabah: JOGANGOHutan, 2006 citing McMorrow and Talip, 2001;
1957: Sothi Rachagan, 1998
1966: Peninsular: JOGANGOHutan, 2006 citing Jomo et al., 2004; Malaysia: ABC and WCMC, 1997; Sabah: JOGANGOHutan, 2006 citing McMorrow and Talip, 2001; Sarawak: own calculation, based on 1966 total Malaysia minus Peninsular and Sabah;
1974: Peninsular: JOGANGOHutan, 2006 citing Jomo et al., 2004;
1981: Sabah: McMorrow and Talip, 2001;
1984: Peninsular and Sarawak: JOGANGOHutan, 2006 citing Jomo et al., 2004; Sabah: McMorrow and Talip, 2001;
1985: Sabah: Rautner et al., 2005 citing Sabah Forestry Department;
1991: FAO Forestry Department, 2002;
1995: Sarawak: Rautner et al., 2005 citing Forestry Department of Sarawak;
2000: Peninsular and Malaysia: Stibig and Malingreau, 2003;
2001: FAO Forestry Department, 2002;
2003: Sarawak and Sabah: Rautner et al., 2005;
2005: MTC et al., 2007.

Figure 37 depicts the location of natural forest and other land use types in Sabah.

Besides the national classification of PFE, state land forest and national and wildlife reserves, Sabah also has its own forest classification, which divides forests into protection forest, commercial forest, domestic forest, amenity forest, mangrove forest, virgin jungle forest and wildlife reserves (see also Appendix A for a definition of Sabah's forest classes). The results for year 1996, 2004/2005 and 2007/2008 are presented in Table 61. It can be seen that total forest reserves have remained stable between 1996 and 2007. A very slight increase was caused by an increase in protection forest. It is important to note that the forest areas of Sabah presented in Table 61 do not necessarily show primary forests. For 1990, Marsh and Greer (1992) already found that nearly one third (98 000 ha) of the 316 000 ha where secondary forest.

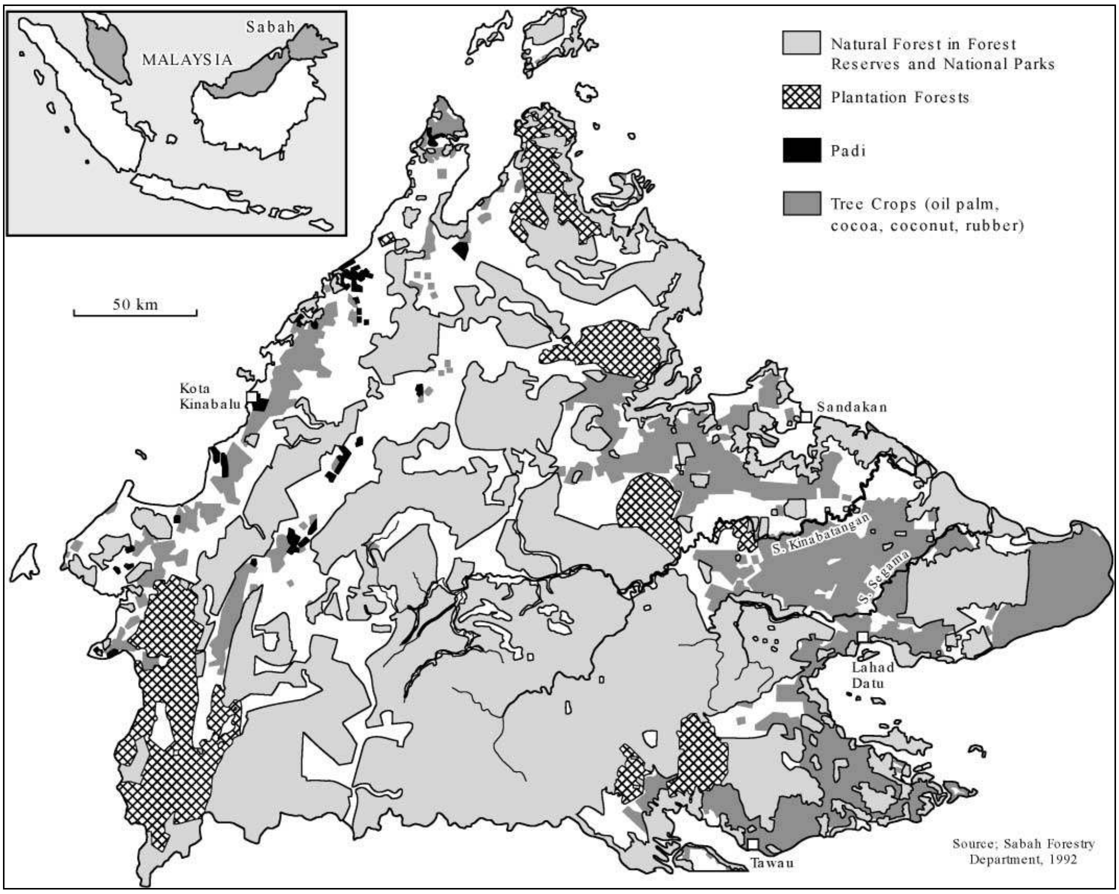

Figure 37: Natural forests, plantations forests and major crops in Sabah (1992)
Source: McMorrow and Talip, 2001

Table 61: Forest reserves in Sabah, by class

		1996	2004/2005	2007/2008
Class I	Protection forest	283	342	348
Class II	Commercial forest	2744	2685	2683
Class III	Domestic forest	7	7	7
Class IV	Amenity forest	21	21	21
Class V	Mangrove forest	316	316	321
Class VI	Virgin jungle forest	90	90	92
Class VII	Wildlife reserves	132	133	133
Total	Total	3595	3594	3605

Source: **1996:** McMorrow and Talip, 2001
2004/2005: Rautner et al., 2005
2007/2008: Sabah Forestry Department, 2008b

Appendix H: People and Organisations Contacted

Person contacted	*Company/Organisation*	*Topic*	*Communication*
Ballayan, Dominic	FAO / ESSG	Agricultural land definitions	email
van den Berk, Vincent	Eur Cie / FLEGT programme	Forest statistics and timber trade Malaysia	E-mail
Burgers, Paul	Utrecht University	Estimation of grasslands Indonesia	visit; email
Carle, Jim	FAO / FOMR	Statistics on timber and other plantations	email; phone
Diemont, Herbert	Alterra (WUR)	Peatland Indonesia	email
Ellenbroek, Wim	WWF the Netherlands	Estimation of deforestation Indonesia	visit; email
Geerts, Bas	UTZ Certified	Mapping of palm oil plantations Indonesia	email
George, Hubert	FAO / NRLA	Degraded Land Statistics	email
Harrison, Adam	WWF Scotland	Estimation of degraded land Indonesia	email; phone
Van den Hende, Petra	Dutch Ministry of Agriculture, Nature and Food	ISRIC land suitability study	email; phone
Leegwater, Marieke	Productschap Margarine, Vetten en Oliën (MVO)	Palm oil statistics Indonesia	visit
Lynden, Godert van	ISRIC (WUR)	Degraded lands (Universal Soil Loss Equations)	email
Mantel, Stephan	ISRIC	ISRIC land suitability study	email
Nachtergaele, Freddy	FAO / NRLA	Degraded Land Statistics (LADA and GLASOD)	email
Ozinga, Saskia	FERN London	Forest degradation and palm oil statistics Malaysia	email, phone
de Roo, Adrie	Dutch Ministry of Agriculture, Nature and Food	Forest degradation and land use statistics Malaysia	email
Schillings, Luc	Dutch Ministry of Agriculture, Nature and Food	Forest degradation and land use statistics Malaysia	email
Silvius, Marcel	Wetlands International	Estimation of peatland forests	email; phone; visit
Susanto, Purwo	WWF Indonesia	Estimation of deforestation	email
Vel, Jacqueline	University of Leiden / Van Vollenhoven Instituut	Law, governance and development	email
Wakker, Erik	AIDEnvironment	Palm oil plantation statistics Malaysia	email, phone
Wielaard, Niels	Sarvision	Mapping of palm oil plantations and deforestation	visit; email
Wolvekamp, Paul	Both Ends	Deforestation; land degradation Indonesia	email
Van der Zijden, Hans	Dutch embassy in Jakarta	Stakeholders involved	email