Friends of the Earth

June 8, 2007

James Boyd, Vice Chair; Presiding Member, Transportation Committee, CEC
Jeffrey Byron, Commissioner; Associate Member, Transportation Committee, CEC
Robert Sawyer, Chairman, ARB
California Energy Commission
Docket Office
Attn: Docket 06-AFP-1
1516 Ninth Street, MS-4
Sacramento, CA 95814-5512

Dear Commissioner Boyd, Commissioner Byron, and Chairman Sawyer:

Friends of the Earth greatly appreciates the opportunity to comment on the scenario analyses presented at the May 31st Joint Workshop on the State Alternative Fuels Plan.

We have included comments on the overall report and on the specific scenario analyses.

Public Participation

We commend the efforts of staff at both CEC and CARB to involve the public and allow meaningful input throughout the State Alternative Fuel Planning process. We are, however, deeply concerned that we have not been given an opportunity to comment on a draft publication of the State Alternative Fuels Plan. Stakeholders must be given the opportunity to comment on how the various scenario analyses will coalesce to form a coherent set of recommended policy options. We recognize that the agencies involved have been operating under significant time constraints, but it is essential that the public be given an adequate opportunity to review the proposed Plan and to provide input and feedback to staff. It is also critical that staff have adequate time to consider and incorporate public comment. We recommend that a draft or interim report be issued to meet legislative deadlines and that the comment period remain open for thirty days following the publication of the Plan.

It was indicated by Commissioner Boyd at the May 31, 2007 Joint Workshop that continued review and refinement will occur throughout the CARB's eighteen month Low Carbon Fuel Standard (LCFS) rulemaking process. While we look forward to providing substantive comment on the critically important LCFS process as well, it cannot be considered a substitute for meaningful and transparent review of the AB 1007 State

Alternative Fuels Planning Process. The objectives of these two processes, while complementary, are distinct.

We would also like to emphasize the importance of continued full transparency as the State Alternative Fuel planning process moves forward.

Clarity and Consistency in Scenario Analyses

Among the seven fuel scenario analyses provided as part of the alternative fuels plan, there is a significant degree of inconsistency in the presentation and content, making comparison among fuels unduly difficult. We strongly recommend that all scenario reports be revised to ensure they share a common structure and common terms of reference. This is a necessary step for comparing the costs and benefits of fuels for purposes of policy recommendations, including any funding decisions that may be made in the future.

Assumptions must also be clearly stated and all analytical modeling tools employed must be made publicly available for comment and review. Where data gaps and uncertainties exist, they should be clearly stated and pinpointed for further public input and agency review.

Not all scenario analyses included a discussion (or analysis) of how the Low Carbon Fuel Standard would affect scenario results. To ensure that the State Alternative Fuels Plan adds to the benefits achieved by this program, it is critical that the Full Fuel Cycle Analysis and the Scenario Analyses are amended periodically to incorporate changes occurring to fuels as a result of the LCFS.

We have also noted with concern that the Scenario Analyses lack a consistent approach regarding the inclusion mid-term fuel technologies in the analyses. For example, battery electric vehicles do not appear to be considered as part of the electric drive scenario analysis whereas algae and cellulosic feedstocks are considered in the Renewable Diesel and Ethanol Scenario Analyses, respectively.

Further, the fuels considered in the Full Fuel Cycle Assessment (FFCA) lack consistency with the fuels considered in the Scenario Analyses. It is therefore not clear how greenhouse gas emissions values are derived in the Scenario Analyses, given that many feedstocks were not included in the original Fuel Cycle Assessment.

Synchronize Fuel Categorizations and Definitions

It would be helpful if fuel categories and definitions remained consistent throughout all reports. For example, renewable diesel and XTL diesel were not used as fuel categories in the Full Fuel Cycle Analysis.

Life Cycle Analyses

An environmentally and economically sustainable implementation of AB 1007 will require a more thorough life cycle assessment of all transportation fuels. As we have commented previously, CEC and CARB must expand the Full Fuel Cycle Analyses to include the full range of parameters affecting greenhouse gas emissions and other environmental impacts. As noted in greater detail below, land-use changes and high input farming practices can (and have been demonstrated to) have a significant effect on the greenhouse gas emissions values of some feedstocks.

Renewable Diesel

As the Low Carbon Fuel Standard (2007) report confirms, significant uncertainty exists as to the greenhouse gas benefits of renewable diesel feedstocks. We are particularly concerned about the greenhouse gas implications of land-use changes (slash and burn rainforest clearing practices), high input farming (fertilizer use) and nitrogen-fixing legume feedstocks (soy beans) associated with biofuel production.

We are concerned that foreign supplies of renewable diesel, like soy and palm, will be used to meet the majority of near-term demand in California (Renewable Diesel Scenario Analysis, p.5). We are including a number of studies as appendices to this comment that illustrate the potentially significant increase in greenhouse gas emissions from foreign soy and palm oil production. We ask that CEC and CARB amend the Full Fuel Cycle Analysis to take these significant land use impacts into account in assessing the life cycle impacts of renewable diesel feedstocks.

Both the LCFS (2007, p. 30) technical report and the draft Full Fuel Cycle Analysis (Well-to-tank Report, 2007 Figure 7-17) rely solely on Midwest soybean feedstocks for biodiesel greenhouse gas emissions values. In contrast, the Renewable Diesel Scenario Analysis indicates that other countries will supply a significant portion of renewable diesel demand in California (p.5). The likelihood that biodiesel feedstocks will come from outside the U.S. was highlighted in testimony at the workshop, where biodiesel industry representatives noted that neither California nor the U.S. would be able to supply sufficient feedstocks and requested agency support in ensuring sufficient infrastructure to support imports

According to the Stern Review (Peston, 2006), 18% of global emissions result from deforestation. As governments across the world increasingly mandate or incentivize biofuel production without corresponding safeguards in place, the drive to expand cropland production imperils both rainforests world-wide and the international community's greenhouse gas stabilization targets. This is particularly true in Brazil and Indonesia where soy and palm oil, respectively, drive rainforest destruction.

Palm oil can have exceedingly damaging environmental and greenhouse gas impacts. Malaysia and Indonesia together account for 85% of palm oil production with 28 million metric tons in 2004-05 (FAS, USDA 2006, Table 16). A large fraction (~27%) of palm oil production in Malaysia and Indonesia occurs on peatland and is expanding at an increasing rate to meet Western demand for biodiesel. Wetlands International, in consultation with Delft Hydraulics (2006), estimates that production of one ton of palm oil causes between 10 and 30 tons of CO2 emissions through peat oxidation (assuming productions of 3 to 6 tons of palm oil per hectare, under fully drained conditions and excluding fire emissions).[1]

Ethanol Scenario

As the Low Carbon Fuel Standard (2007) confirms, significant uncertainty exists as to the greenhouse gas benefits of ethanol production. As noted previously, we are particularly concerned about the greenhouse gas implications of land-use changes and high input farming associated with biofuel production.

The state should recommend feedstock production and refining methods that have clear greenhouse gas emissions benefits and meet all other air, water, and public health objectives set forth in Assembly Bill 1007. Continuation of existing incentives and the development of new incentives must be allocated to feedstocks that demonstrate the greatest greenhouse gas emission reductions and the greatest environmental benefit. To ensure that these goals are met, any recommendation that results in a substantial increase in biofuel production or consumption in California must be accompanied by environmental safeguards to protect our lands, forests, water, wildlife, public health and climate.

XTL Scenario Analysis

The state should not use scarce resources to promote XTL fuels. XTL fuels are prohibitively expensive and are proven to increase greenhouse gas emissions.
We are concerned about the assumed 10% greenhouse gas benefit of XTL fuel use (Scenario Analysis for Penetration of XTL Fuels, 2007 p.2, footnote).[2] This assumption does not appear to be grounded in the draft Full Fuel Cycle Analysis available for public comment, nor is it explained how this figure is derived.

The Environmental Protection Agency calculates that the lifecycle greenhouse gas emissions of a gallon of liquid coal are more than double the emissions of gasoline. Wang et. al. (2007) found that even if 90% of emissions from the production process could be captured and sequestered, liquid coal would still generate higher emissions than gasoline.

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[1] The paper referenced here is a consultancy report; a scientific paper on methods and results is intended to be published in the scientific journal Ecology this year. The current total peatland CO2 emission of 2000 Mt/y equals almost 8% of global emissions from fossil fuel burning. These emissions have been rapidly increasing since 1985 and will further increase unless action is taken. Over 90% of this emission originates from Indonesia, which puts the country in 3rd place (after the USA and China) in the global CO2 emission ranking.

[2] The XTL powerpoint presentation at the May 31st Joint Workshop indicates an assumed greenhouse gas emissions benefit of +-10% for GTL and +-200% for CTL. The report does not indicate however that it is discussing only GTL. This is a significant oversight and must be corrected.

The Department of Energy (DOE) predicts commercial-scale sequestration will not be available until at least 2015, and perhaps much later at significant cost and with remaining considerable uncertainty about the ability to permanently sequester greenhouse gas emissions. In addition, because of the large amounts of coal required to make a barrel of liquid fuel, the launch of a large-scale liquid coal industry would further increase the devastating effects of coal mining felt in many communities and ecosystems stretching from Appalachia to the Rocky Mountains, including polluted air and water and destroyed landscapes.

Electric Drive Scenario Analysis

We commend the CEC and the CARB for analyzing a range of on and off road applications of various electric drive technologies. However, we ask that battery electric vehicles (BEV) be analyzed in the Electric Drive Scenario Analysis. This is a technology that is on the road today and that has significant potential to reduce greenhouse gas emissions. In this time of ever higher gasoline prices and greater number of cars per household, it is likely that BEVs will find a niche in many homes.

Periodic Review

We recommend that CEC and CARB update and review the State Alternative Fuels Plan and the full fuel cycle assessment in an annual or biannual review to reflect changes in: the best available science, modeling tools, markets, consumer acceptance, production technology, farming methods, land uses, etc. Additionally, the assumptions that underlie the Full Fuel Cycle Assessment must be amended to included a market equilibrium analysis.

Vehicle Miles Traveled

We commend the CEC and the CARB for recognizing the importance of reducing travel demand and vehicle miles traveled as a guiding objective in the “2050 Vision” document. The state alternative fuel planning process should establish specific mechanisms to decrease travel demand and vehicle miles traveled.

Conclusion

We support the prudent use of sustainably produced alternative fuels that meet the twin goals of reducing global warming pollution and breaking our dangerous dependence on foreign oil. We also support the efforts of the California Energy Commission (CEC) and the California Air Resources Board (CARB) to evaluate alternative fuels on a full life-cycle basis.

In a world of limited resources, the Alternative Fuels Plan should prioritize among fuels that are proven to provide clear greenhouse gas, public health, air, and water quality benefits. In doing so, CEC and CARB can help ensure the state’s resources will be used most effectively to increase alternative fuel development and use while optimizing environmental and public health benefits.

Sincerely,

Danielle Fugere,
Regional Program Director
FRIENDS OF THE EARTH

Kate Horner,
Program Associate

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LIFE CYCLE ASSESSMENT OF ENERGY PRODUCTS:

ENVIRONMENTAL ASSESSMENT OF BIOFUELS

- Executive Summary -

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Abstract

The objective of this study is to evaluate the environmental impact of the entire production chain of fuels made from biomass used in Switzerland. Firstly the study supplies an analysis of the possible environmental impacts of biofuels suitable as a basis for political decisions. Secondly an "environmental life-cycle analysis" (LCA) of the various biofuels is done, which can be used as a basis for granting an exemption from the excise duty on hydrocarbon oil. In addition, the impacts of fuel use are compared with other uses for bioenergy such as the generation of electricity and heat. The study based on the Swiss database of environmental inventories ecoinvent gives a holistic comparison of the environmental impacts of biofuels; however neither the costs of biofuels nor the social consequences of their production are evaluated. The results refer to average values from the year 2004 in the respective production countries and are to be taken as a snapshot of factors relevant to the fuels' use in Switzerland. Thus the study cannot provide any answers to questions concerning future impacts – for instance, on food prices.

In principle, each of the fuels examined (bioethanol, biomethanol, biodiesel and biogas) can be produced in an environmentally friendly way – it depends on what raw materials and production technologies are used. Most of the environmental impacts can be attributed to the agricultural cultivation of the respective raw materials (feedstocks). The environmental impact from fuel processing is usually much lower. The environmental impact from the transport from the production site to Swiss filling stations is even less, even when the biofuels are produced overseas. The present study shows that with most biofuels there is a trade-off between minimizing greenhouse gases (GHG emissions) and a positive environmental LCA. It is true that GHG emissions can be reduced by more than 30% with a number of biofuels. However most of these supply paths show greater impacts than petrol for various other environmental indicators.

The environmental LCA was done using two different methods: one was the Swiss method of ecological scarcity (Environmental Impact Points, UBP 06), which evaluates the difference between environmental impacts and legal limits. The other one is the European Eco-indicator 99 method, which quantifies the damage done to human health and ecosystems. Both methods show the same results: in the case of tropical agriculture it is primarily the slashing and burning of rainforests that releases the largest quantities of CO2, causes an in-crease in air pollution and has massive impacts on biodiversity. In the moderate latitudes it is partly the lower crop yields, partly the intensive fertilizer use and mechanical tilling of the soil that are the causes of a bad environmental evaluation. However unlike the case of fossil fuels, the environmental impacts of biofuels can be greatly reduced by specific measures. The study shows in sensitivity analysis how, for instance, a reduction in methane leakage can improve the LCA of biogas production or what effect a prohibition of slash and burn would have on the LCA of biodiesel made from palm oil.

Overall, the results of the study show that any promoting of biofuels by a tax break, for instance, must be done so as to target the best production paths. Not all biofuels per se can reduce environmental impacts as compared to fossil fuels. Currently, of all the production paths investigated, it is especially the use of biogenic wastes ranging from grass to wood that brings a reduction in environmental impact as compared with petrol. Since the potential of domestic bioenergy today is limited – and will be so in future – bioenergy will not solve our energy problems. However it if the available biomass is transformed into energy in an efficient and environmentally friendly manner, while at the same time consumption is reduced and energy efficiency in-creased, these alternative energy carriers can together with other forms of renewable energy play a role in our future energy supply that should not be neglected.

Executive Summary

In connection with the worsening scarcity of fossil fuels and climate change the idea of using renewable energy is attracting interest both in the Swiss public eye and in industry. Fuels made from biomass – so-called biofuels – are currently the most important form of renewable energy in road transportation and could at least over the short to medium term take on a role in reducing greenhouse gases and our dependency on fossil fuels.

In Switzerland therefore important political decisions have to be made against a background of giving a tax break for renewable fuels as opposed to diesel and petrol.

Although biofuels from renewable resources exist, a wider range of environmental impacts may result from their cultivation and processing than those from fossil fuels. These range from excessive fertilizer use and acidification of soil to a loss of biodiversity caused by slash and burning rainforest. Besides that, one should not forget that expanding agricultural energy production may lead to land use conflicts with other land uses such as food production or the conservation of natural areas. Therefore energetic efficiency and the attainable reduction in greenhouse gases should not be taken as the sole criteria for a holistic environmental evaluation of these alternative fuels.

The objective of this study is to evaluate the environmental impacts in the whole process chain of biofuels used in Switzerland. Firstly an action-oriented analysis of the environmental impacts of renewable energy carriers was to be developed. Secondly the objective was to draw up a "comprehensive environmental analysis" of the various biofuels, which could serve as a basis for enforcing the exemption of renewable fuels from the excise duty on hydrocarbon oil. In addition, the effects of using the fuel were to be compared with other ways to use bioenergy, such as heat and power generation.

Methodology

In order to determine the effects of biofuels on the environment as exactly as possible, the methodology of life cycle assessment (LCA) was chosen. That entails evaluating the energy and resource consumption and all pollutant emissions over the entire life cycle needed to satisfy a defined function (e.g. filling up a car tank with 1 MJ of energy at a Swiss filling station). The necessary inventory data for biofuels were collected in an initial subproject and complemented by additional data from the Swiss environmental inventory database (ecoinvent 1.3). The impacts on the environment were then first determined with the aid of **action-oriented indicators**, which described the direct environmental impacts and suggested to us ways to deal with them. Secondly an **environmental overall assessment** was done, during which the individual damaging effects were weighted and aggregated, so that all environmental impacts could be assessed (see Figure 1). It was important to remember that the aggregated evaluation methods (in this study Environmental Impact Points[1], UBP 06, and eco-indicator 99 [2]) included their own relative weighting factors for the various environmental impacts (e.g. the greenhouse effect versus excessive fertilizer use). For political discussion it is therefore important not to rely solely on the overall evaluation, but rather on a case-by-case basis to include the individual action-oriented indicators it is based on.

The study covered renewable energy forms both from Switzerland and foreign production; however Switzerland was always taken the place of utilization. The assessment was done on a cradle-to-grave basis; i.e. all relevant environmental impacts from biomass cultivation, from the occurrence of a biogenic waste substance to its energetic utilization. The year 2004 was chosen as the main observation period, although in some cases we had to rely on older or newer data.

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[1] The method of ecological scarcity (UBP 06). The mass unit consists of environmental impact points. This Swiss method estimates the total environmental impact from the difference between emission values and the legal limits.

[2] A fully aggregated environmental evaluation method based on the proliferation and damaging effects of emissions.

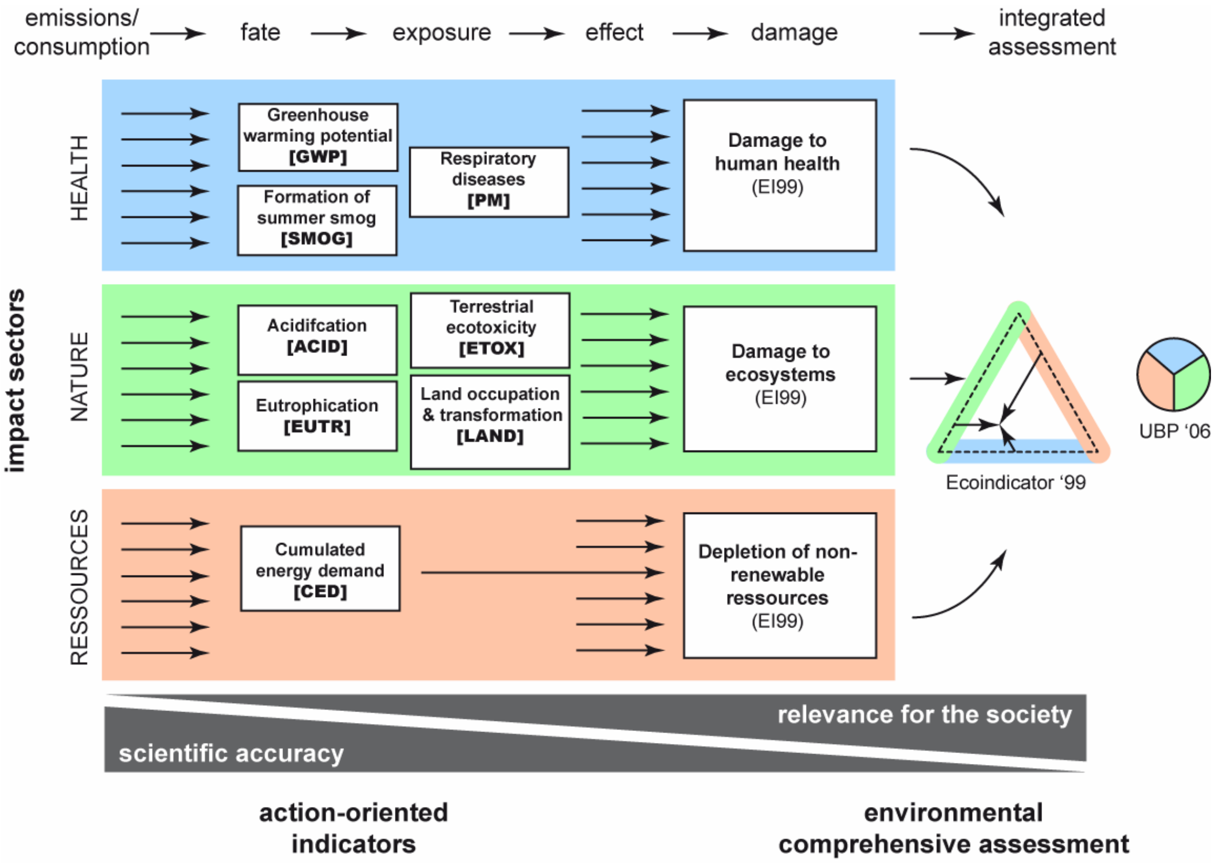


Figure 1 **Schematic diagram of the environmental indicators used in the study along the path of proliferation and causation**

One important aspect in analysing renewable resources is the inclusion of co-products. During the production of the products examined in this study there are co-products on various production stages which required us to allocate the environmental impacts onto multiple products. Thus it was necessary e.g. to distribute the raw material inputs and environmental impacts from the pressing of rapeseed grains over the two resulting products rapeseed oil and rapeseed cake. This allocation was done during the preceding data collection according to economic criteria in most cases, i.e. environmental emissions were distributed in the same proportion as the revenue obtained from each of the products.

Limitations of the study

The methodology does provide a holistic comparison of bioenergy forms considering the whole production chain. However the approach suffers from the following limitations as regards the interpretation of results:

- The methodology of life cycle assessment (LCA) analyses the environmental impacts of material and energy flows. That does not include any results pertaining to economic factors such as e.g. costs or social factors such as e.g. child labour.
- Although the LCA approach used here is very comprehensive, certain environmental impacts are covered only incompletely or not at all. For example, the effects of water utilization are not covered because they differ a lot depending on local conditions (the quantity of precipitation, groundwater level, etc.). Biodiversity losses are also incomplete because the data basis is lacking on tropical ecosystems.
- The assessment approach calculated only the primary environmental impacts of the process chain, e.g. energy consumption and pollutant emission during the cultivation of energy rapeseed. Secondary effects, though, were not covered. (For instance, food was grown beforehand on the energy rapeseed field. Afterwards food had to be imported causing additional transports, and thus additional environmental impacts.)
- No distinction is made with cultivation biomass (e.g. grain or potatoes) between harvest wastes and biomass produced specifically for fuel production. Nor does the method differentiate between the use of already cultivated fields and newly cultivated fallow fields, and thus neglects the envi-

ronmental impacts associated with them as well, such as a reduction in biodiversity in the latter case.

- On the basis of the data from existing Life Cycle Inventory Analysis (LCIA) most of the results refer to existing process chains, and thus cover Reference Year 2004; future developments are not judged. However a glimpse of future developments is provided by the sensitivity analyses and possible optimization potentials.
- Since many allocations have been calculated from sales revenue, and revenue depends on market dynamics, the results of this study are not "chiseled in stone" and may have to be verified at some later point in time.
- The process chains investigated represent only a subset of all production processes; many more production paths are conceivable. The paths chosen, however, are considered especially relevant for the current situation in Switzerland.
- The data from existing LCIA represent average condition in the respective production countries (Switzerland, Europe, Brazil, USA, etc.) and apply as an integral whole as regards use in Switzerland. Therefore the results may not be applied without qualification to decision situations in partial regions or individual plants, because the environmental impacts in individual cases may differ radically from the average situation.
- The study gives no answers the question as to the future consequences of a shift to renewable fuels, e.g. the consequences for the environment if agricultural products were to be grown on such a large scale for energetic utilization that agricultural production as a whole had to be intensified, or as to any possible rebound effects [3] in case an increase in fuel consumption should result from the introduction of biofuels because biofuels were regarded in the eyes of consumers as "environmentally friendly", and thus as unproblematic.

How are environmental impacts distributed along the value chain?

Figure 2 provides a chart of how greenhouse gas emissions (GHG emissions) are distributed along various production chains for bioethanol, biodiesel, methanol and methane.[4] The figure shows that savings of up to 80% are possible as compared with fossil fuels depending on the biofuel and production path. However large differences arise along the production chain:

- The largest percentage of GHG emissions comes from **agricultural cultivation** (Figure 2, green) through the use of machines, fertilizer and or pesticides, and also in the form of direct emissions (such as nitrous oxide). By the same token however, this percentage can be varied a lot. The most important factors for agricultural GHG emissions are yield per area (high in the cases of Swiss sugar beets or Brazilian sugar cane, but low in the case of Swiss potatoes or rye RER), emission of nitrous oxide (comprising 30% in the case of US maize) and the slash-burning of rainforest (relevant with Malaysian palm oil and Brazilian soy oil). The regional differences in the intensity of deforestation can have a relevant effect on the overall result. The main factor is the way in which energy plants are cultivated. This applies not only to GHG emissions but also to the most of the other environmental impacts of biofuels as well. Unlike agricultural products, waste and leftover materials require no energy to be reused; this has a very positive effect on their overall balance. Thus the lowest overall GHG emissions are attainable when using biodiesel made from waste cooking oil or methane from liquid manure.
- **The fuel production itself** (Figure 2, yellow) causes on average much lower GHG emissions than agricultural cultivation. Biodiesel requires only low emissions during extraction and esterification. During the fermentation of bioethanol the emissions can be varied a lot because either fossil energy carriers have been used (bioethanol from American maize) or waste from agricultural production is used as process energy (bagasse in the case of Brazilian sugar cane). The highest GHG emissions in the production process are set fee during the production of biogenic methane. The causes for this are the methane and nitrous oxide emissions during the secondary fermentation of the residue and the methane leakage during the processing step from biogas to methane 96% by

[3] A rebound effect occurs whenever an efficiency gain causes an increase in consumption, and the latter destroys the advantages of the efficiency gain.

[4] Biogenic ETBE was also looked at in this study. However because it is similar to ethanol as regards its environmental impacts, the main difference being that it has a lower CO2 reduction effect because only about half of ETBE is based on biomass, it has not been represented separately in this Executive Summary.

volume. Figure 2 shows, though, that for instance in the case of liquid manure much of these emissions can be reduced by taking care to cover the secondary fermentation container.[5] This covering up has already become state-of-the-art as of 2007.

- **Fuel transport** *per se* (Figure 2, orange) from the production regions to the Swiss filling station usually comprises much less than 10 % of overall emissions and plays only a secondary role from an environmental standpoint – as long as the intercontinental transport is done with tank ships or in pipelines.
- The actual **vehicle operation** (Figure 2, dark grey) is CO_2-neutral in the case of the pure biofuels compared here because all the CO_2 set free then was shortly before absorbed during plant growth.

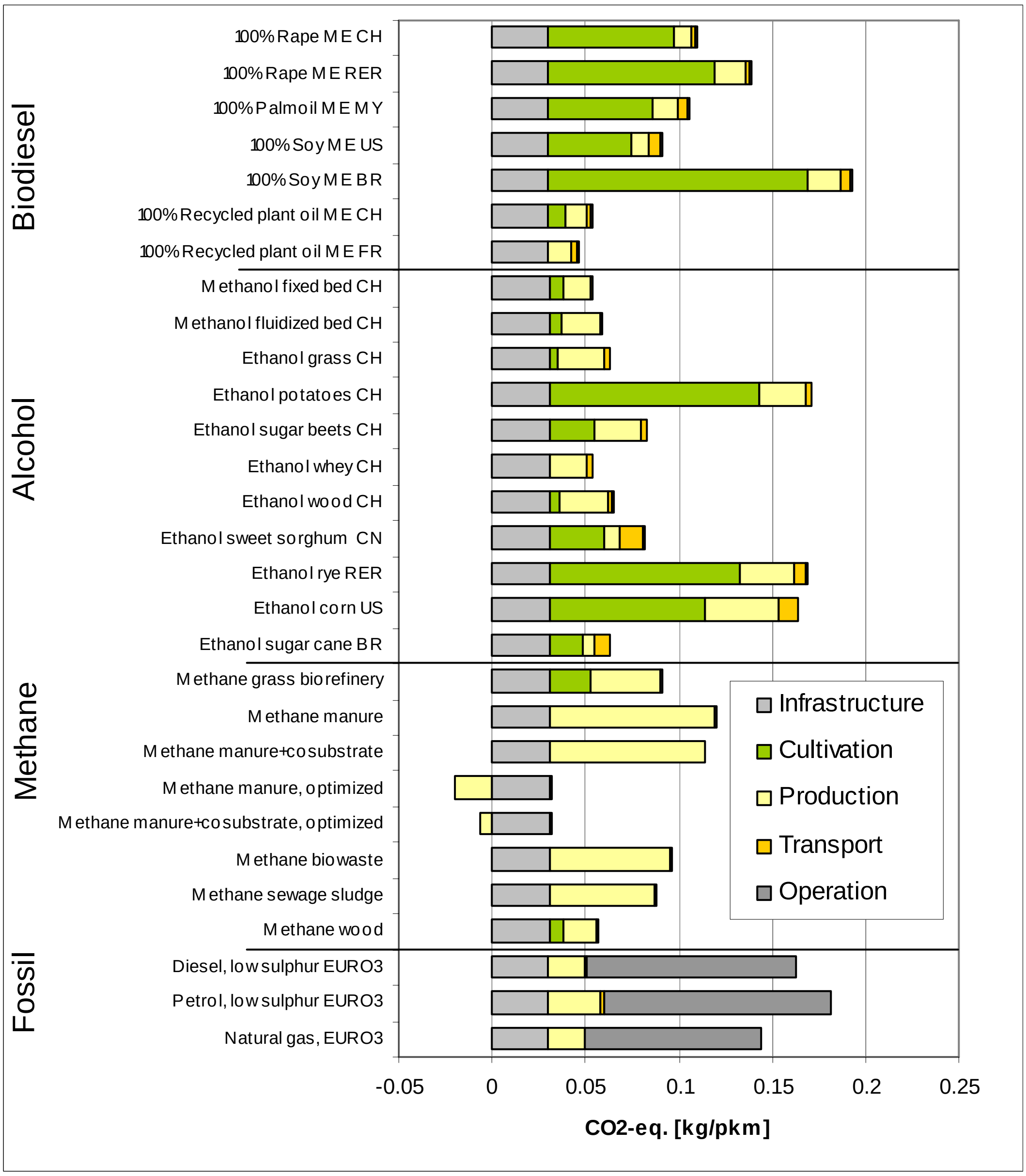


Figure 2 **Comparison of the greenhouse gases emitted by biofuels in comparison to those emitted by fossil fuels (petrol and diesel, EURO3). The emissions are broken down into the individual process of the value chain.**

- The **production and maintenance of vehicles and construction and maintenance of roads** (Figure 2, light grey) has also been dealt with in this study. However an identical vehicle and the same annual mileage were assumed for all cases considered, yielding the same increment for all

[5] The GHG emissions in the case of *methane from liquid manure, optimized* are negative because this case is based on the difference between them and the emissions during agricultural output of the unfermented liquid manure.

variations. In the case of very efficient alternative fuels such as bioethanol from sugar cane or methane from liquid manure this increment may comprise much more than half of all GGH emissions.

Figure 3 shows a different picture in which the whole environmental impact has been calculated using the method of ecological scarcity (UBP 06). It is true that the environmental impacts of vehicle operation (dark grey) are much higher when fossil fuel is used in comparison to biofuels; however this is overcompensated by the many very high environmental impacts in agricultural production. The causes of this are soil acidification and excessive fertilizer use in European and Swiss agriculture. In the case of tropical agriculture it is biodiversity loss, air pollution caused by slash-and-burn and the toxicity of pesticides some of which are forbidden in Switzerland that comprise the essential causes of the severe environmental impacts. The very high impact in the utilization of Swiss potatoes can be explained by the great importance placed on nutrient leaching. The very high values for rye taken from European production, on the other hand, can be explained by the low harvest yield of rye on an overall European average.

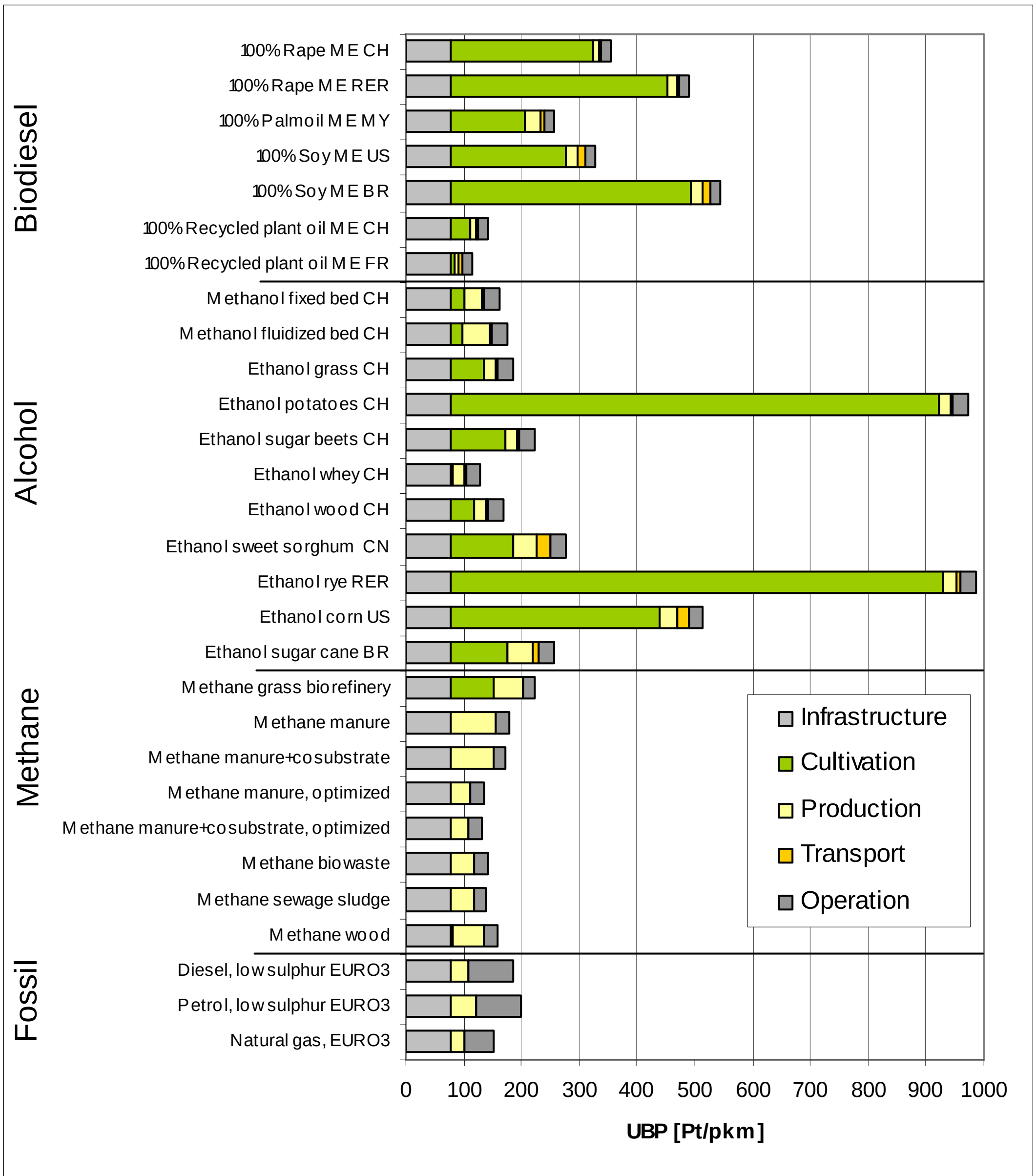


Figure 3 **Comparison of aggregated environmental impact (method of ecological scarcity, UBP 06) of bio fuels in comparison with fossil fuels (petrol, diesel and natural gas). The environmental impact is broken down by individual processes of value chain.**

Should biofuels be imported from abroad?

Transporting biofuels from abroad to a Swiss filling station causes only a low percentage of the GHG emissions (Figure 2), and individual imported biofuels such as bioethanol from Brazilian sugar cane get a good environmental evaluation similar to that for the best domestic biofuels. The reason for this is that transportation modes such as oceangoing tankers or pipelines are used that require relatively small amounts of energy and cause only low pollutant emissions.

It is still questionable whether the import of biofuels on a large scale makes sense in the long run. Firstly, the biofuels could be used in the countries of production, in order to lessen the dependence on oil imports there; secondly, the great demand for biofuels has caused a rapid expansion of production areas and thus also rising food prices and increased pressure on rainforest areas. As soon as the slash-and-burn technique is used, the GHG balance and the whole LCA get much worse, thus making importation questionable.

Which biofuels are the most environmentally friendly?

An integrated environmental assessment begins with summarizing many environmental indicators in an appropriate way. That requires value judgments. The primary motivation for granting a tax exemption for biofuels comes from their potential to reduce GHG. Therefore the first environmental requirement for a fuel tax reduction is the quantity of GHG saved. This study has been based on the following threshold values:

- **A GHG reduction of at least 30% as compared with the fossil reference (petrol, EURO3[6])**

However these GHG reductions should not be had at the expense of some other form of environmental impact, which may take various forms with biofuels. Therefore another important requirement for an integrated environmental evaluation is the criterion:

- **No increasing impacts in other relevant environmental impacts as compared with the fossil reference (petrol, EURO3)**

These two criteria were applied to the LCA of this study, as evident in Figure 4 (see the page after next). It became apparent that 13 other various biofuels had GHG reductions of more than 50% and 5 of them were produced from waste materials. The largest reductions were attained with biofuels made from liquid manure. The other fuels that had GHG reductions of more than 50% were: biodiesel made from waste cooking oil, methanol and methane from wood and bioethanol from domestic biomass (grass, wood, sugar beets or whey), Brazilian sugar cane and Chinese sorghum. 9 fuels (four of which were from waste materials) still had a GHG reduction of more than 30%, one of them produced from biodiesel made from various agricultural products (soy oil US, palm oil MY, rapeseed oil CH) and the fermentation of various waste material to biogenic methane. The worst case was 5 alternative fuels attaining less than 30% GHG reductions; an extreme one being Brazilian soy biodiesel, the emissions of which turned out to even a little higher than those from petrol.

Whereas the Cumulated non-renewable Energy Demand (CED)[7] correlates with the GHG emissions, the situation is different with the other environmental indicators. With the summer smog potential (SMOG) it is especially the tropical alternatives that have high values because the cultivation areas are often accessed by means of slash-and-burn or – in the case of bioethanol from sugar cane – the dry leaves are burned off before the harvest. Excessive fertilizer use (EUTR) was higher, as had been expected, by several factors in the cases of agricultural processes than in those of fossil fuels. In the case of Brazilian sugar cane and with Malaysian palm oil it became apparent, however, that even these factors can be kept low by using less fertilizer, and high crop yields can still be attained. Ecotoxicity (ETOX) on the other hand shows peaks with cultures that are grown on slash-and-burn areas that are due to the high toxicological evaluation of acetone emissions. The only biofuels investigated that

[6] EURO 3 is the European pollutant standard for passenger cars that has been in force since Jan.2000. Since emissions are compared with reference to mileage, it is necessary to define a pollutant standard.

[7] Total quantity of non renewable energy needed for the production and supply of a product (in our case a biofuel).

stayed below the level of petrol in all environmental impacts tested here were methyl ester made from waste cooking oil and methane from sewage and biowaste.

Because of the environmental impacts caused by agricultural cultivation the overall evaluation (Figure 5) of Swiss bioethanol production from whey shows an overall impact that is reduced by up to 30% (UBP 06) or 50% (Eco-indicator 99) depending on the test method. The other domestic supply paths for bioethanol show the same or even better values than petrol in the overall evaluation. An overall evaluation reduced by up to 30% (UBP 06) or 50% (Eco-indicator 99) can also be obtained with the production and use of biogenic methane, although in some cases the GHG emissions are increased due to methane leakage. Figure 5 shows the confidence interval in which 95% of all values lie. This confidence interval covers only the risks in the gathering of the inventory data (for instance, when estimating energy consumption) and the risks inherent in the evaluation methodology (e.g. the probability that cancer would develop given the emission of a certain quantity of carcinogenic substances). The risks are relative small, especially when using the UBP methodology, but also with the estimation of GHG emissions, and cause a change in the evaluation (from green to red or vice versa) only in special cases. On the other hand the risk is very high with all agricultural processes in the Eco-indicator 99-evaluation. The cause of that is the evaluation of land use, which – primarily for methodological reasons – bears a high risk.

Figure 6 and Figure 7 summarize the GHG emissions and overall environmental evaluation of all fuels studied. The green area means a better evaluation than the fossil reference both as regards GHG emissions and in the overall environmental evaluation. The figures show on the one hand that there are production paths for all fuels in the green area; on the other hand, most of those “green” production paths are based on waste materials and residue. Bioethanol from Brazilian sugar cane shows very different evaluations depending on whether UBP 06 or Eco-indicator 99 was used. The cause of this is the pesticide Daconate, which contains a lot of arsenic, a chemical in this study only to be found in the inventory of sugar cane cultivation and that causes high ecotoxicology readings when evaluated using Eco-indicator 99. The great differences in bioethanol from potatoes can be explained, on the other hand, through the great importance attached to nutrient leaching in the UBP 06 method.

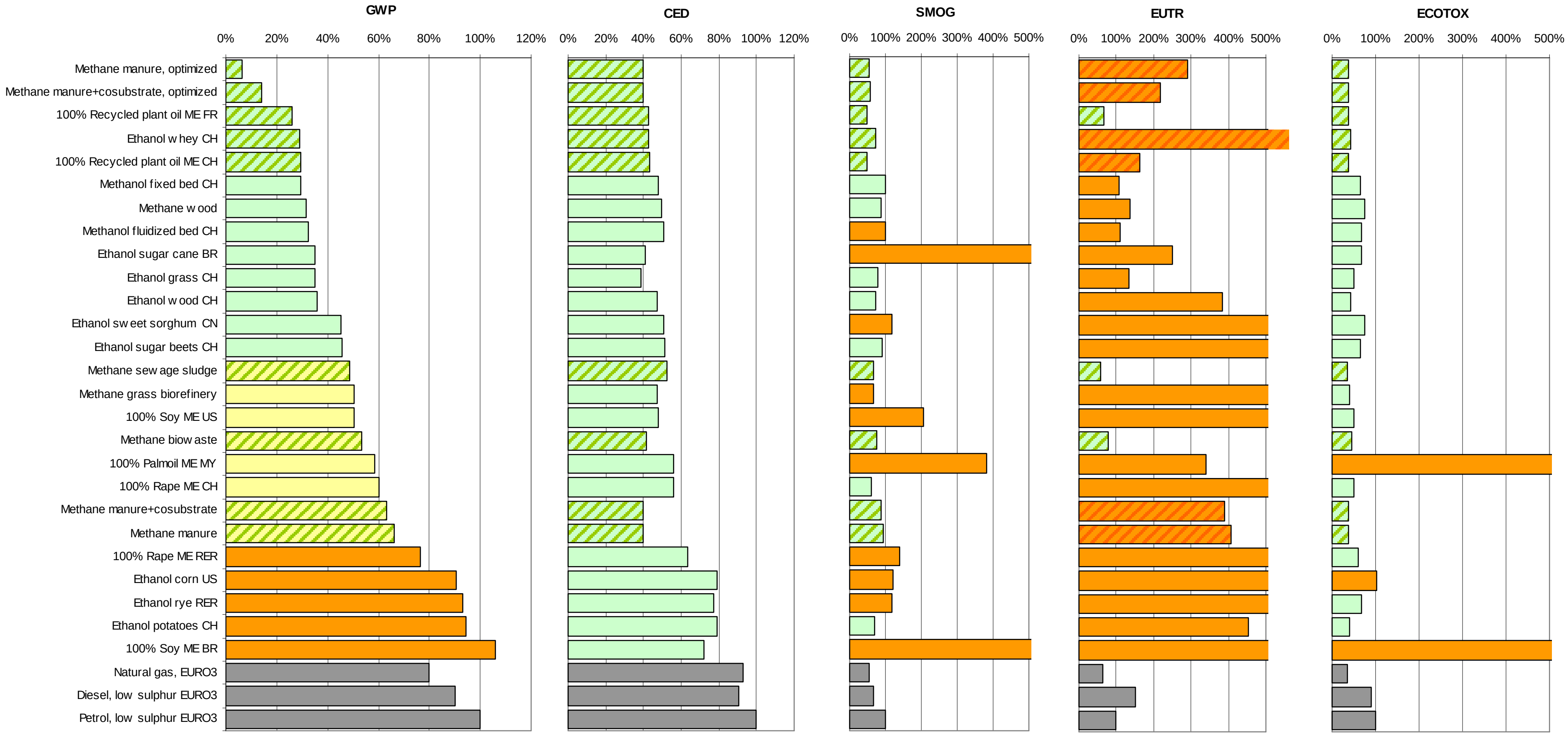


Figure 4 **Overall environmental Life Cycle Assessment of all unblended biofuels studied in comparison to fossil reference. GWP = greenhouse warming potential, CED = cumulated non-renewable energy demand, SMOG = summer smog potential, EUTR = excessive fertilizer use, ETOX = ecotoxicity. Reference (= 100%) is petrol EURO3 in each case. Biofuels are shown in diagram at left ranked by their respective GHG emission reductions. Fuels that have a total GHG emission reduction of more than 50% as versus petrol are shown in green, those with GHG emissions reductions of more than 30% are yellow, those with GHG emissions reductions of less than 30% are red. In other diagrams green = better than reference; red = worse than reference. Cross-hatched fields = production paths from waste materials or residue.**

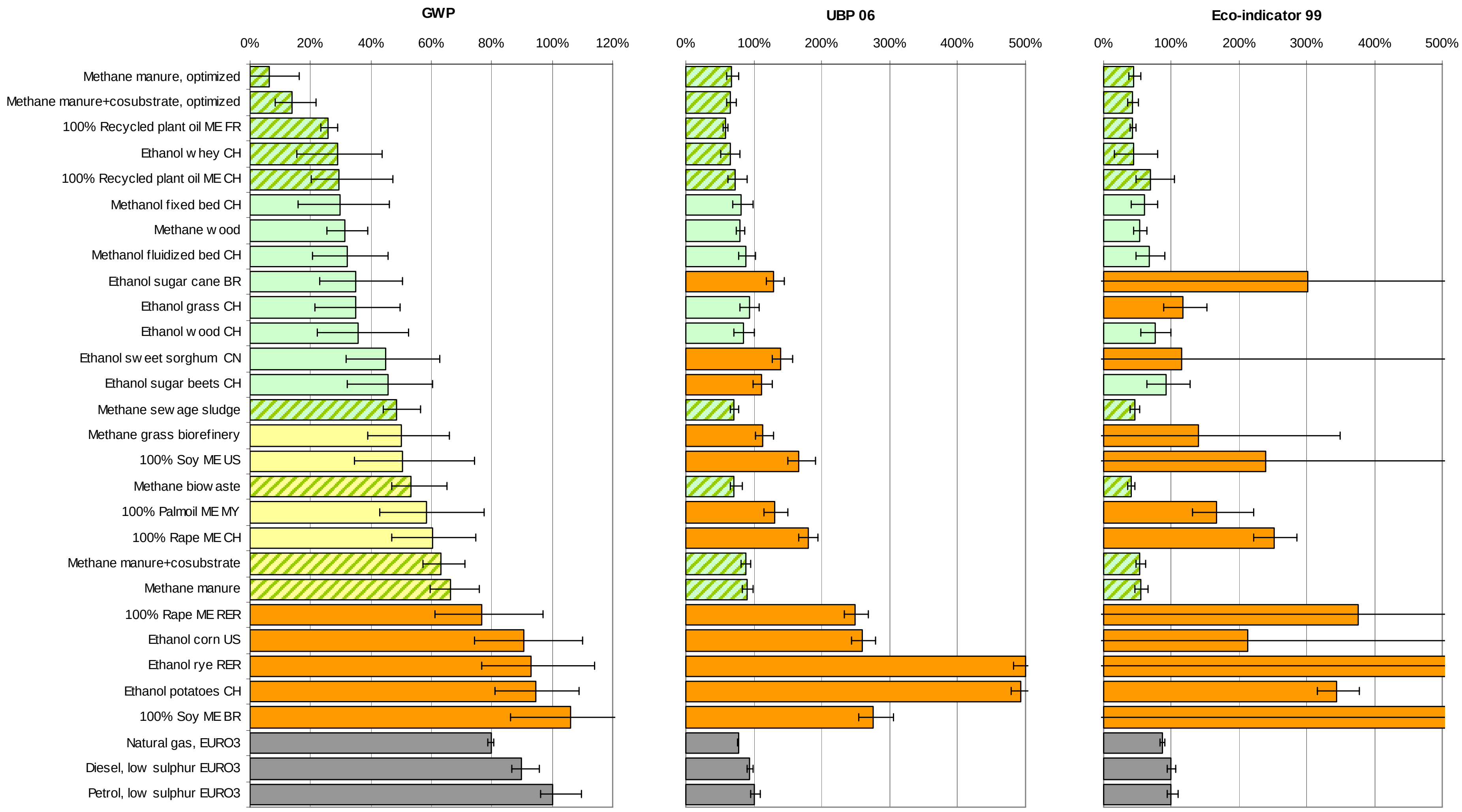


Figure 5 **Overall environmental Life Cycle Assessment of all unblended biofuels studied in comparison to fossil reference. GHG emissions reductions of more than 30% are yellow, GHG emissions reductions of less than 30% are red. In other diagrams green = better than reference; red = worse than reference. Cross-hatched fields = production paths from waste materials or residue. Error bar = 2.5 % / 97.5 % percentiles calculated using Monte Carlo simulation.**

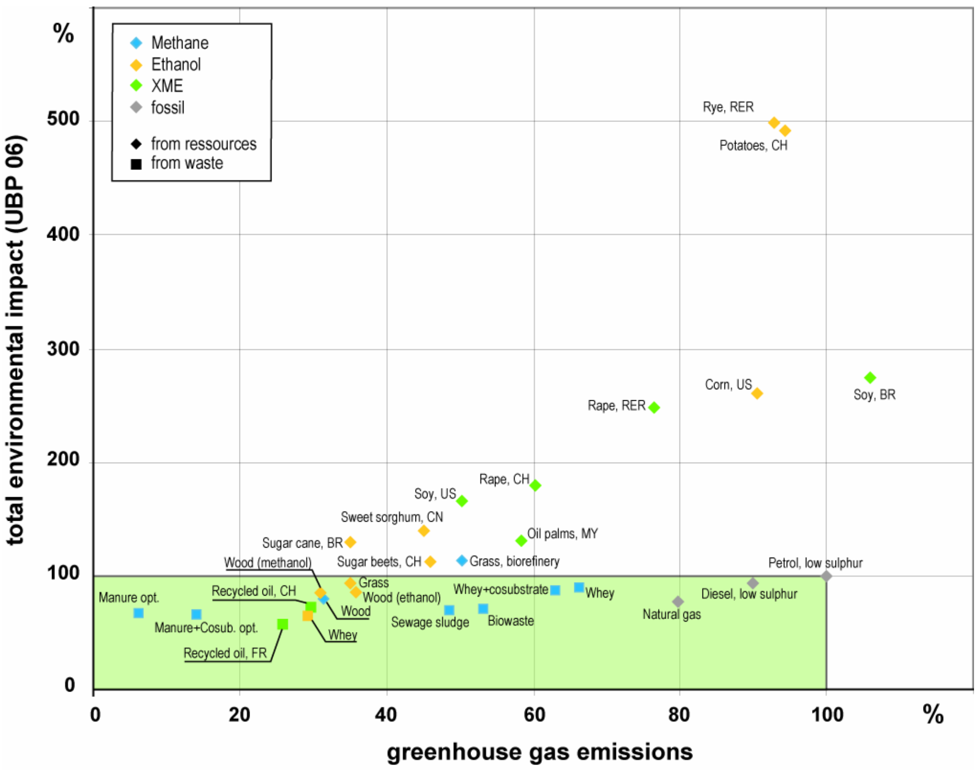


Figure 6 Two-dimensional representation of GHG emissions and overall environmental impact (UBP 06). Values are relative to fossil reference petrol. Green area means both lower GHG emissions and lower overall environmental impact than petrol.

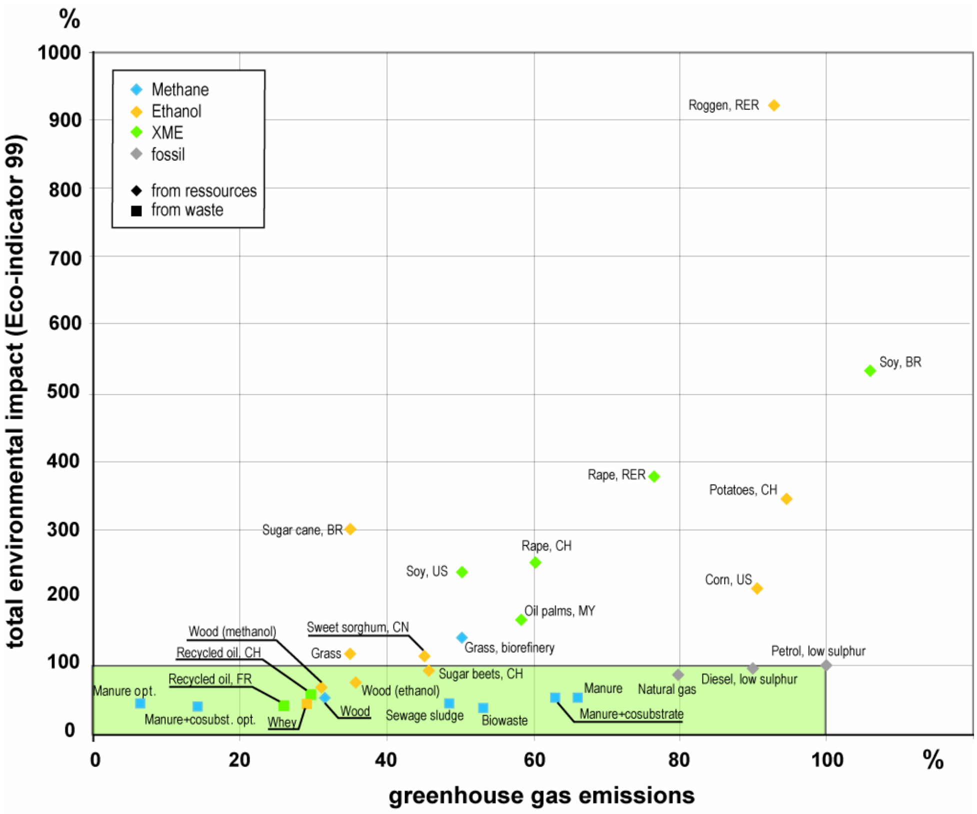


Figure 7 Two-dimensional representation of GHG emissions and overall environmental impact (Eco-indicator 99). Values are relative to fossil reference petrol. Green area means both lower GHG emissions and lower overall environmental impact than petrol.

How high are the environmental impacts of fuel production per land unit?

Figure 8 shows the GHG emissions per hectare and year in comparison to the mileage that can be attained with the biomass grown on that hectare. The figure reveals great differences in agricultural cultivation, both as regards energy yield and GHG emissions.

The highest mileage can be attained with bioethanol from domestic sugar beets. The sugar beets give about the same hectare yield as Brazilian sugar cane (approx. 70 t/a), but have a slightly higher saccharose content than sugar cane because of the much lower fiber content. If one compares the mileage / ha with the GHG potential/ha, Brazilian bioethanol shows the greatest distance from the correlation line and thus the best ratio.

When one takes the cultivation forms "IP", "extenso" and "bio" among domestic agricultural products, there are lower GHG emissions obtainable with potatoes, rye, grass and rapeseed in extensive cultivation; however the mileage declines in a similar way, so no clear preferences can be seen.

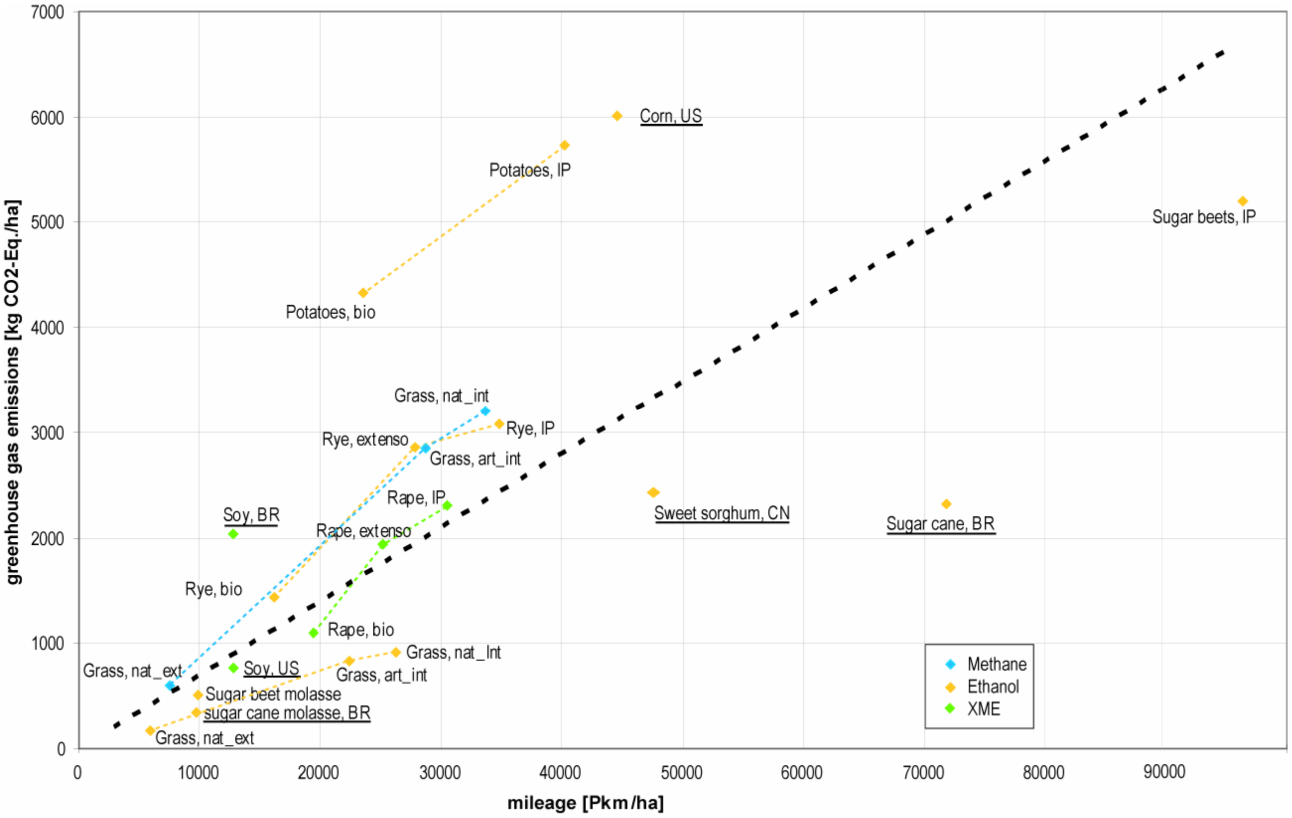


Figure 8 **Two-dimensional representation of mileage and GHG impact per hectare for various energy plants. Black dotted line represents mean value (linear regression). Colored dotted lines connect various cultivation forms of respective products. Underlined = foreign product.**

Which energetic utilization is the most environmentally friendly?

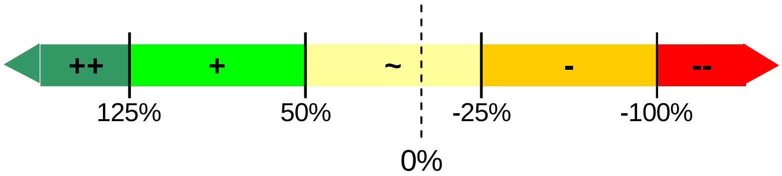
Biogenic energy carriers such as wood, biogas or ethanol can be used for purposes other than fuel; they can also be used for heat and / or electric power, for instance. Not all these utilization possibilities are equally advantageous when seen from an environmental perspective because they involve different percentages of conventional energy carriers, many of them fossil. Therefore in this study we asked in a second stage what energetic utilization is the most environmentally friendly? This entailed calculating the resulting net utility for various biogenic energy carriers using the following formula:

Net utility =	environmental impact avoided by using substitutes for fossil energy carriers **-** environmental impact (produced) by using biogenic energy carrier XY

The functional unit for these tests was a certain quantity of biogenic energy carrier (for instance, 1 kg of whey). This quantity yielded a certain quantity of energy to be used as heat, electric power or transportation. The environmental impacts of this quantity of energy and the quantity of fossil energy it is substituted for were calculated using the above formula, and then the net utility.

It was not possible within the scope of the present study to analyse all the ways that biogenic energy carriers can be used; instead this study has been limited to those cases for which specific data were gathered in the first part of the project including the utilization possibilities contained in the database ecoinvent. The study was limited to a comparison with those energy carriers that are common today, i.e. primarily fossil energy carriers.

Below you will find the results of the utility comparison for the stages Global Warming Potential (GWP) and the overall evaluation (using Eco-indicator ’99 and the method of ecological scarcity, Version 2006) of all energy carriers tested. The following color scheme has been used to represent this summary:



This scale shows how high the utility of a biogenic secondary energy carrier is in comparison to its environmental impact. Since the primary interest is on a positive net utility, a scale has been used that is 25% asymmetrical. (Calculation example: 1 kg of biowaste as fuel yields a net utility given a GWP of 0.13 kg CO_2-Eq. The requirement for fermenting biowaste to methane is 0.39 kg CO_2-Eq. Thus the calculation follows: 0.13 kg/0.39 kg, corresponding to 33% and thus yielding a result according to the scale above of ~ for the range “-25% to +50%“).

energy carrier / use path	Wood		Grass		Manure		Waste wood		Whey		Biowaste		Sewage sludge	
	min	max	min	max	min	max	min	max	min	max	min	max	min	max
Heating	++	++												
Cogeneration (CHP)	++	++	+	++	++	++			++	++	~	+	++	++
Car (methane)	++	++	+	+	++	++	++	++	+	+	~	~	+	+
Car (ethanol)	++	++	++	++					+	+				
Municipal solid waste incineration "average technology"							++	++			~	~	--	--
Municipal solid waste incineration "latest technology"											++	++		
Cement kiln							++	++					~	~

Figure 9 **Net utility in relation to Global Warming Potential. Table shows all variations investigated in Chapter 4, where utility is plotted relative to environmental impact of biogenic secondary energy carrier (see text for explanations). Chapter 4 investigated two scenarios for production of conventional electrical power and heat respectively – causing net utility to fall somewhere between a minimal (“Min” column) and maximal value (“Max” column). White fields indicate variations not investigated.**

use path / energy carrier	Wood		Grass		Manure		Waste wood		Whey		Biowaste		Sewage sludge	
	min	max	min	max	min	max	min	max	min	max	min	max	min	max
Heating	~	++												
Cogeneration (CHP)	~	++	~	~	+	++			+	++	-	-	+	++
Car (methane)	+	+	~	~	++	++	+	+	+	+	~	~	++	++
Car (ethanol)	~	~	+	+					++	++				
Municipal solid waste incineration "average technology"							~	+			-	-	--	--
Municipal solid waste incineration "latest technology"											+	++		
Cement kiln							+	+					-	-

use path / energy carrier	Wood		Grass		Manure		Waste wood		Whey		Biowaste		Sewage sludge	
	min	max	min	max	min	max	min	max	min	max	min	max	min	max
Heating	~	+												
Cogeneration (CHP)	~	+	+	++	+	++			-	-	-	-	~	++
Car (methane)	~	~	+	+	+	+	~	~	-	-	-	-	~	~
Car (ethanol)	~	~	++	++					++	++				
Municipal solid waste incineration "average technology"							-	-			-	-	--	--
Municipal solid waste incineration "latest technology"											-	-		
Cement kiln							+	+					-	-

Figure 10 **Net utility in relation to overall evaluation on basis of Eco-Indicator 99 (at top) and on basis of UBP 06 (at bottom). Table shows all variations investigated in Chapter 4, where utility is plotted relative to environmental impact of biogenic secondary energy carrier (see text for explanations). Chapter 4 investigated two scenarios for production of conventional electrical power and heat respectively – causing net utility to fall somewhere between a minimal ("min" column) and maximal value ("max" column). White fields indicate variations not investigated.**

The result for the **GHG emissions** in Figure 9 correlates with that for the cumulated non-renewable energy requirement (KEA). In most cases the utility is 50 and more % greater than the impact that using he biogenic energy carrier entails. However the situation does not look as positive only for the two secondary energy carriers biowaste and sewage with their high water content because using them often entails a whole series of drying steps connected with fossil energy consumption.

If one does an **overall LCA** using the methodologies **Eco-Indicator 99 and UBP 06**, one gets a somewhat more optimistic picture, as shown in Figure 10. However here too it becomes apparent that it is not so simple to find a biogenic energy carrier that gives positive results both as regards GHG emissions and environmental LCA. Utilization of liquid manure (from farms) brings the best results – as it shows up as good to very good in the two methods used. The use of biowaste, however, shows a much less positive picture. The main reason for that is the heavy-metal emissions that are released when the fermentation mass is used in agricultural crops.

A horizontal perspective that compares the various utilization possibilities (use in a CHP plant, as fuel, etc.) show positive and less positive sometimes even negative cases everywhere. Current-day incinerators do not appear to be very efficient in using biogenic secondary energy carriers.

All in all, it can be concluded from the comparisons done that using the biogenic variations tested here as substitutes for traditional fossil energy carriers will bring positive results as regards GHG emissions – i.e. less environmental impact. However many of the variations tested display clear disadvantages when compared with the fossil variations used today in other environmentally relevant aspects, so that an environmental LCA certainly does not produce positive results for using biogenic energy carriers in all cases.

Conclusion

The present study shows that with most biofuels a trade-off exists between minimizing GHG emission and a positive environmental LCA. It is true that reductions in GHG emissions of more than 30% can be obtained with many biofuels; however the most of the production paths display higher impacts than petrol in various other environmental indicators. The transport of foreign biofuels into Switzerland is of only secondary importance. Instead, the manner in which the biofuel is produced is much more important.

The central finding of this study is that most of the environmental impacts of biofuels are caused by agricultural cultivation. In the case of tropical agriculture this is primarily the slash-and-burning of rainforests which sets great quantities of CO_2 free, causes air pollution and has severe impacts on biodiversity. Concrete certification guidelines for biofuels that counteract these problems, for instance, like the guidelines of the *Forest Stewardship Council* (FSC) are urgently needed. In the moderate latitudes it is partially the low crop yields, partially the intensive fertilizer use and mechanized tilling that cause the unfavorable environmental impacts. Then one should search for an optimal ratio of energetic yield and low environmental impact through variety and crop rotation. A favorable LCA could also be achieved with the energetic utilization of agricultural co-products such as molasses or sorghum straw.

It is the energetic utilization of waste materials and residues that wins the prize in this study because firstly the high impacts from the supply of raw materials are avoided, and secondly the environmental emissions can be reduced that otherwise would come from waste treatment such as waste water degradation with whey or the methane emissions that result from fertilizing with unfermented liquid manure. One critical factor is the high methane emission that at times comes from the production and processing of biogas. In this area as well, the overall LCA could be much improved by taking appropriate measures. On the one hand, these are already being done with new plants, whereas on the other hand, research work needs to be devoted to the separation of CO_2.

The energetic utilization of wood also brings good results because the environmental impacts of supply of the raw material are very low. One possible technology for the future is the gasification of wood, if ever GHG-active methane emissions can be minimized through closed processing. However even if such processes are to be regarded as future perspectives, an evaluation of their future significance must still be left open due to the limited availability of the raw material and the many competing alternative forms of utilization.

The results of this study show on the whole that promoting biofuels, for instance, through a tax break, must be done in a differentiated way. Not all biofuels are *per se* suitable to reduce environmental impact as compared to fossil fuels. Of all the production paths tested, at present it is primarily the utilization of biogenic waste material and wood and the utilization of grass for ethanol production that bring a reduction in environmental impact as versus the fossil reference. Nonetheless the environmental impact of biofuels – unlike that of fossil fuels – can be reduced a lot by appropriate measures. Because of this optimization potential, one may expect that in future it will be possible to achieve better results for a number of production paths. In addition to this, innovative processes such as Biomass-To-Liquid (BTL) will become more important, although it has not been possible to include them in this study.

The potential of domestic bioenergy is limited today – and will remain so in future. If energy plants were cultivated in Switzerland on a large scale, it would have a negative influence on the food self-sufficiency of the country, or would cause added environmental impact by requiring the intensification of food production. Therefore our energy problems will not be solved by biofuels alone. Only if the biomass is transformed into energy efficiently and in an environmentally friendly way, while consumption is reduced and energy efficiency increased, could these alternative energy carriers play a role in our future energy supply that should not be neglected in conjunction with other renewable energy forms.

WWF for a living planet®

Rain Forest for Biodiesel?

Ecological effects of using palm oil as a source of energy

A study by WWF Germany in cooperation with
WWF Switzerland and WWF Netherlands

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Cover photo: Palm oil seedlings in a plant nursery. Central Kalimantan, Indonesia.
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Contents

Summary

Palm oil is an extremely versatile commodity which traditionally has been used both as a foodstuff and as a raw material in non-food items such as cosmetics, soaps, shampoos and washing detergent. Only recently, with rising mineral oil prices and challenges from climate change, have there been calls for palm oil to be used as a renewable energy source.

In Europe, the production and use of vegetable oils as energy sources are influenced by prevailing political and legal conditions, such as tax exemption as provided under the Renewable Energy Act in Germany or the recent European Union directive on promoting use of biofuels in the transport sector as a way to cut greenhouse gas emissions.

Like other vegetable oils, palm oil can be used as a fuel in vehicles or for electricity or heat generation. But for it to be used as a biofuel, it either has to be processed to make it similar to mineral diesel fuel, or vehicles and machines have to be modified to accept pure vegetable oil. Furthermore, the palm oil biodiesel must comply with existing fuel quality standards of several countries. Poor fuel quality has often been the main cause of machine breakdowns. In Europe, palm oil currently does not fulfil the standards‘ specifications relating to melting points. There is though enormous potential for the use of palm oil as a biofuel if the standards soften this demand. More vegetable oils could then be used in their pure form or as part of a mix in power stations, depending on their size. Already, around 1.5 million tonnes of palm oil were used in this manner in power stations throughout Europe in 2005.

More than 80 per cent of the world‘s palm oil is produced in Indonesia and Malaysia. Significantly smaller amounts are grown in Nigeria, Thailand and Colombia. Palm oil outranks soybean, rapeseed and sunflower in terms of output per hectare. It is feared that if demand for palm oil increases further, valuable tropical forests in the producing countries will fall victim to the intensive cultivation of oil palms.

On the surface, the use of palm oil as an energy source appears environmentally-friendly as it replaces fossil fuels and is CO_2 neutral. But what if the entire production chain of turning palm oil into a biofuel is taken into account?

This study examines the issue more closely. It was undertaken by the Institute for Energy and Environmental Research and the Institute for Climate, Environment, Energy, both of Germany, and commissioned by WWF in Germany, Netherlands and Switzerland. The study investigated the environmental effects of oil palm cultivation, looking at various land-use changes and calculating the corresponding energy balances and greenhouse gas balances.

The life cycles of conventional diesel and biodiesel were compared when considering the energy balances. Differentiations were made between palm oil use for vehicles and in power stations. For both uses, it was observed that the production of palm oil biodiesel requires considerable amounts of fossil energy compared to that of conventional diesel. On the other hand, considerable energy credits result from the by-products of palm kernel oil, such as tenside and glycerine, that are greater than the entire energy expenditure for the production of palm oil biodiesel.

Alternative land-uses play a role in calculating the greenhouse gas balances. For this purpose, various scenarios were developed i.e. use of natural forest, fallow land and plantations of other crops, such as coconut or rubber, for planting oil palm. The natural forest and fallow land scenarios also considered the effects of the different depreciation periods. A further differentiation was made with the natural forest scenario between sustainable and typical management of palm oil plantations.

The study concluded that the use of tropical fallow land for planting oil palm is clearly more effective in terms of CO_2 savings. then clearing of natural forests. The results are not as unequivocal when converting other plantations into oil palm plantations as it depends on the preceding crop. When plantations of other crops are converted into palm oil plantations, it means the products traded on the world market, for eg. natural rubber, will no longer be available and have therefore to be substituted by alternatives such as synthetic rubber. All this needs to be considered.

There are hardly any differences in the energy balances and greenhouse-gas balances when comparing use

of palm oil fuel for vehicles and in power stations. Considerable energy and greenhouse gas savings can be made during the production if this is managed according to „best practice“. Best management practices include the capturing of biogas from oil mill effluents, the use of fibres and kernel shells, and sustainable and optimised production methods.

Compared to the production of other biofuels, the energy balance for cultivating oil palm turns out positive. However, it is only the cultivation of oil palm on tropical fallow land which can be considered positively in terms of greenhouse gas savings. If the oil palm to produce biofuel is grown on plantations of other crops, the balances worsen noticeably.

On the basis of this study, it is evident that palm oil will experience strong growth. The UN FAO has predicted that global demand will double between 2000 and 2030. Several considerations, however, have to be taken into account to ensure that the savings in fossil energy and emissions of greenhouse gases are not offset by negative environmental impacts such as loss of biodiversity, air and water pollution, and social problems such as poor working conditions and land rights conflicts.

Most important as well is the need to ensure that the use of palm oil as a biofuel does not affect its availability as a foodstuff. In most cases, there is a need to ensure that the poor in developing countries who depend on palm oil as a foodstuff do not bear the brunt.

But even if energy balances and climate-gas balances turn out to be positive, environmental aspects should be considered in an overall ecological assessment. This includes, above all, pressures on air and waters arising from palm oil production as well as the loss of biodiversity as a consequence of clearing tropical primary forests.

Considering the risk of palm oil production for nature and environment and a continuous demand for this energy source the actual benefit of palmoil utilisation as a contribution to the reduction of greenhouse gases have to be assessed. In particular the extension of cultivated area should accompany a stringent use of tropical fallows. The efficient application of this option and the assessment of the cost-effectiveness require urgent research.

In order to ensure the sustainable production and use of palm oil, the Roundtable on Sustainable Palm Oil (RSPO) developed guidelines that require minimum social and ecological standards to be met. However, these guidelines have their limits because they are voluntary in nature and they currently do not consider greenhouse gas emissions from the production of palm oil.

In the long run, WWF recommends an international multi-stakeholder process to develop globally applicable sustainability standards for the production of bioenergy.

1 Background and aims

Palm oil has increasingly been at the focus of public discussion recently against the background of various efforts to increase its use as a source of bioenergy. This is also being encouraged by fundamental government policies such as the exemption of biofuels from mineral oil tax, the Renewable Energy Act, the compulsory blending of biofuels with conventional fuels, and the EU's Directive on biofuels' share of total fuel consumption. One important element of this discussion alongside technical and economic issues is the enormous increase in the amount of palm oil that has been coming onto the world market over the last few years, leading in many cases to the clearing of natural tropical forests.

This raises questions as to what potential palm oil has as a source of energy and what effects its increased use as an energy source might have in the future – on the one hand on energy balances and greenhouse gas balances, and on the other on land-use in general and natural tropical forests in particular.

In order to find answers to these questions, the WWF commissioned the IFEU-Institut für Energie- und Umweltforschung Heidelberg GmbH (Institute for Energy and Environmental Research) to gather and evaluate current knowledge on the subject. The present study places the emphasis on the ecological effects, particularly with respect to palm oil's energy balances and greenhouse gas balances and the expected consumption of land. The corresponding technical, economic and political aspects are also examined. The Wuppertal Institut für Klima, Umwelt, Energie GmbH (Institute for Climate, Environment, Energy) also participated in the project, focusing on the political aspects.

The time horizon of this study covers developments expected as a result of the expanded use of first-generation biofuels, which, in addition to the biodiesel made from palm oil and rapeseed oil examined here, also include ethanol made from sugar cane for use as gasoline. According to current estimates, cheaper and more effective second-generation biofuels, such as synthetic BTL (biomass-to-liquid) biofuels made from wood, will reach market maturity around 2020 to 2030; other technically conceivable alternatives such as hydrogen drives or fuel cells are more likely to take until 2030.

2 Palm oil as a source of bioenergy

by Guido Reinhardt, Nils Rettenmaier and Sven Gärtner

Palm oil is an extremely versatile product which up to now has been used predominantly as a foodstuff and as a raw material for bioenergy or other technical purposes. Only relatively recently have efforts been made to use palm oil as a bioenergy source. The methods of growing the oil palms (from whose fruits the palm oil is extracted) and processing the palm oil are identical for all uses.

2.1 Palm oil: cultivation, processing and use

Oil palm cultivation

The oil palm (*Elaeis guineensis* Jacq.) originally comes from west Africa (Gulf of Guinea) and is one of the highest-yielding oil plants in the world producing 3.5-4.0 tonnes of oil per hectare. It grows best on deep and well-drained soils at a mean annual temperature of 24-28°C (with minimal annual and daily fluctuations), a mean annual rainfall of between 1500 and 3000 mm, and a mean relative humidity of 50-70%. It is therefore essentially restricted to the zone of evergreen tropical rainforest on either side of the equator (10°S – 10°N) and to altitudes of up to 500 m above sea level. The oil palm has spread all over the tropics since the mid-19th century and has been grown commercially in extensive plantations since the early 20th century (Rehm & Espig 1996 and Franke 1994).

Picture 1: Oil palm plantation in Malaysia. Photograph: IFEU

Processing the oil fruit

The oil palm‘s main product is its oleaginous fruits, which can be harvested all year. The plum-sized fruit yields two different oils: palm oil (produced from the pulp) and palm kernel oil (from the seeds). After the palm kernel oil has been pressed out, a press cake remains which is rich in protein (15-16% crude protein) and is used as animal feed.

Picture 2: Cross-section of oil fruit. Photograph: IFEU

1 = Palm kernel: palm kernel oil
2 = Pulp: palm oil
3 = Fruit bunches

Uses of palm oil

The properties and uses of vegetable oils are determined by the length of the fatty acid chains, the amount of unsaturated fatty acids they contain, and the number and position of the double bonds. For practical purposes, seven main groups are distinguished.

Due to its high content of oleic acid (about 39%), palm oil – like olive oil – belongs to the oleic acid group; 80% of production is used in foodstuffs (salad/cooking oil, margarine). The remaining 20% is used in the non-food sector (see Table 6). Statistically, its use as an energy source has been minimal up to now.

Palm kernel oil, by contrast (like coconut oil), belongs to the laurinic acid group (laurinic acid content approx. 43%); its content of unsaturated fatty acids is lower (about 17%). These properties, along with the high melting point, are why palm kernel oil is used in long-life bakery products. Because of the high content of short-chain fatty acids (10-14 C atoms), most of production is used by the chemical industry in the production of detergents (Rehm & Espig 1996).

Tab. 1: Uses of palm oil and palm kernel oil

	Foodstuffs	Non-food products
Palm oil	cooking oil, margarine, animal feed, coffee whitener, potato chips	candles, soaps, inks, polishes, tin plating of iron
Palm kernel oil	cooking oil, cooking/frying fat, margarine, confectionery	soaps, ointment base, detergents, cosmetics

Hallmann 2000

2.2 Palm oil – a product in world trade

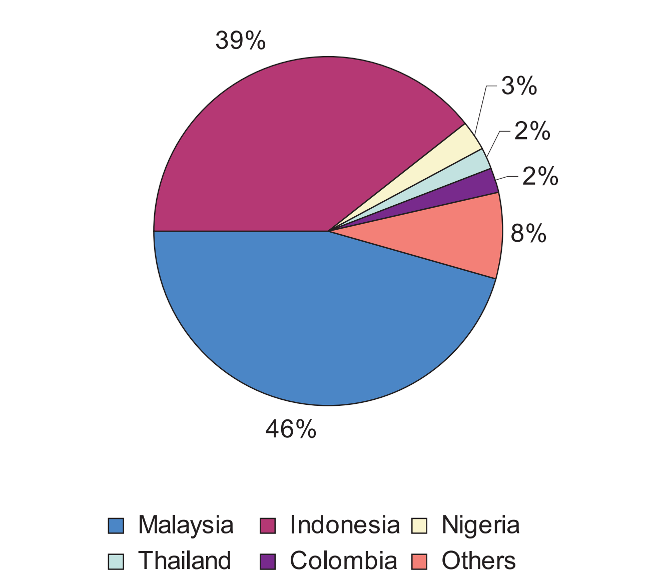
The main cultivation areas of the oil palm are in south-east Asia (Malaysia, Indonesia, Thailand, Papua New Guinea), west Africa (Nigeria, Ivory Coast) and increasingly south and central America (Colombia, Ecuador, Brazil), although it is much less widespread there (see Table 2). Fig. 1 shows that in 2004 about four fifths of the world's palm oil production came from two countries: Malaysia (46%) and Indonesia (39%). A long way behind in third place was Nigeria (3%), followed by Thailand and Colombia (2% each).

Tab. 2: Palm oil: worldwide areas under cultivation and production volumes

	Area [1,000 ha]	Oil production [1,000 t]
Malaysia	3,466	13,976
Indonesia	3,320	12,100
Nigeria	367	790
Thailand	270	668
Colombia	157	632
Others	1,012	2,485
Total	**8,592**	**30,651**

ISTA Mielke 2004

Fig. 1: World palm oil production 2004



ISTA Mielke 2004.

According to the FAO the oil palm is grown on approx. 12 million hectares worldwide (FAOSTAT 2006). However, about 3 million hectares in Nigeria (approx. 90 % of the area cultivated there) are not rated as productive by (ISTA Mielke 2004). Deducting this hectarage, the area cultivated worldwide is slightly less than 9 million ha. The amount of land given over to oil palms has multiplied since the mid-1970s, largely due to rapid expansion in Malaysia and Indonesia (see Fig. 2).

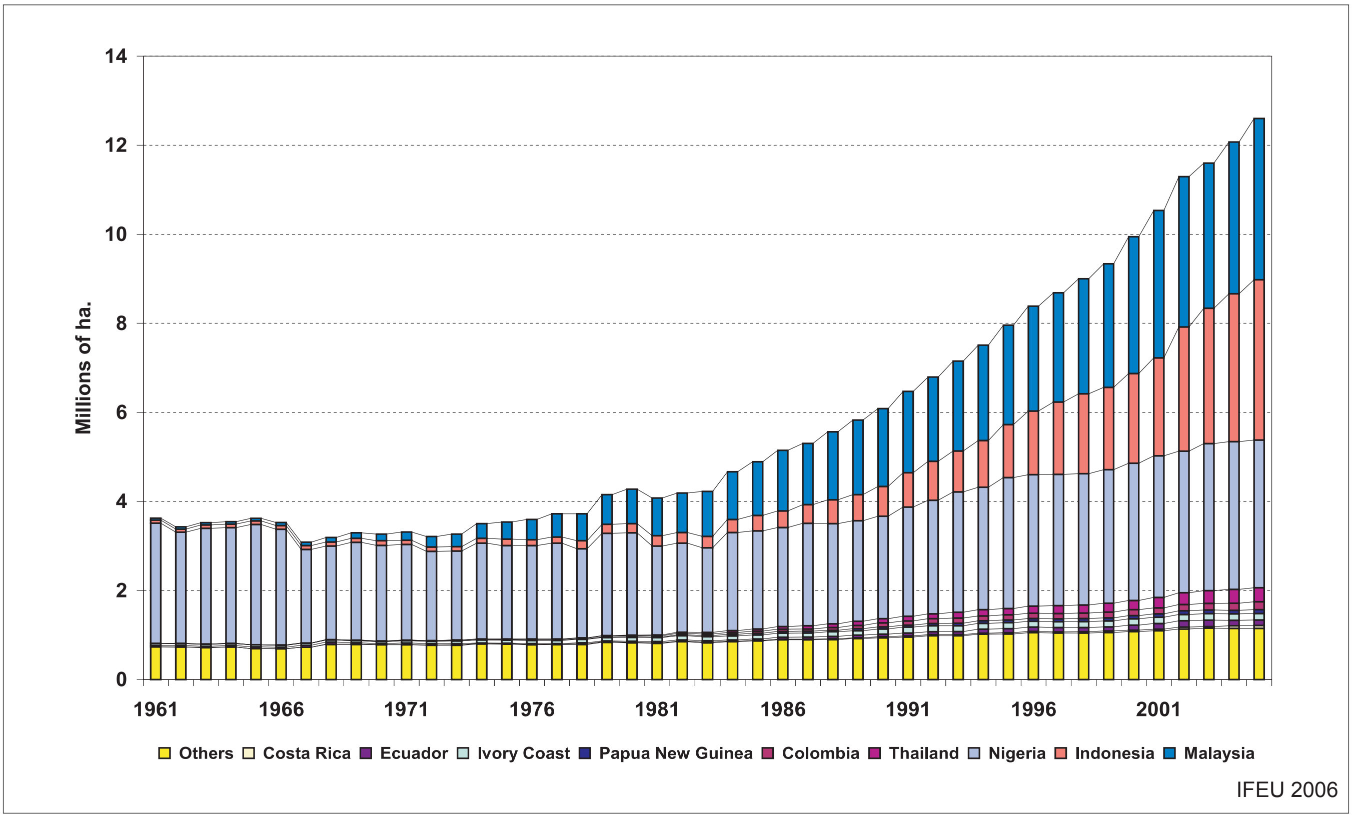
Of all oil crops worldwide, soybean occupies by far the most land (just under 90 million ha.), followed by rapeseed (25 million ha.) and sunflower (20 million ha.). Land devoted to growing oil palm is thus only the equivalent of about 10% of the soy hectarage; even so, it delivers a comparable global output. The reason for this is palm oil's almost ten times higher average yield of 3.57 tonnes per hectare compared to 0.38 tonnes for soybean oil (see Table 3).

Tab. 3: Global average fruit and oil yields of the most important oil crops 1999/2000 2003/2004

	Fruits t/(ha*a)	Oil t/(ha*a)
Cotton seed[1]	1.10	0.12
Peanut[1]	1.42	0.22
Oilseed rape[1]	1.54	0.58
Soybean[1]	2.28	0.38
Sunflower[1]	1.17	0.44
Oil palm[2]	17.84	3.57

[1]USDA 2006
[2]IFEU 2006 (based on ISTA Mielke 2004)

Fig. 2: Worldwide area planted with oil palms



FAOSTAT 2006

With a production of over 30 million tonnes a year, palm oil ranks among the four most important vegetable oils in the world which together make up approx. 80% of the world's output. In 2004/05, palm oil and soybean oil each accounted for about one third (31% and 30% respectively) of production. They were followed by rapeseed oil with 14% and sunflower oil with 8% of global production (see Fig. 3 and Table 4).

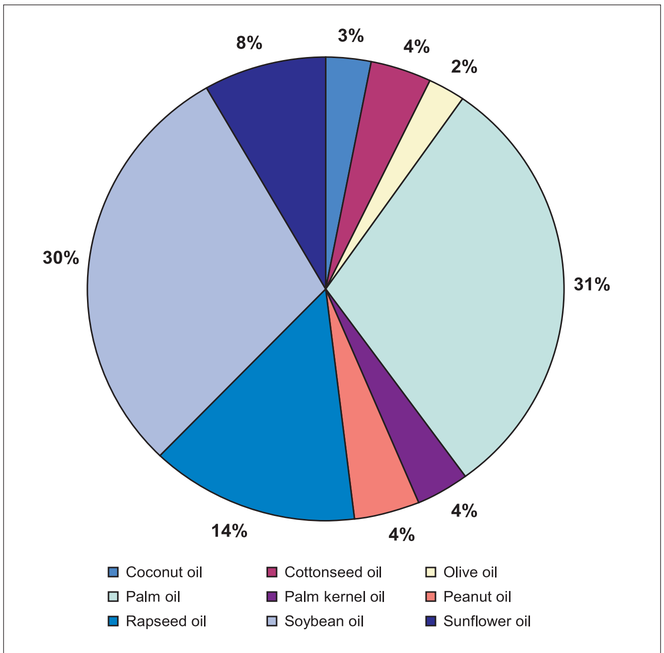
Production of vegetable oils has come to play an important role worldwide, growing by almost 50% over the past eight years to about 110 million tonnes in 2004/05. Palm oil (+96%) and soybean oil (+47%) have been largely responsible for this increase. Production in Malaysia has almost doubled over the last ten years; it even tripled in Indonesia between 1995 and 2004.

Tab. 4: Global production of the most important vegetable oils

	Global production 2004 [m t]
Palm oil	33.24
Soybean oil	32.43
Rapeseed oil	15.67
Sunflower oil	9.18
Peanut oil	4.91
Cotton seed oil	4.75
Palm kernel oil	4.01
Coconut oil	3.26
Olive oil	2.74
Total	**110.19**

USDA 2006

Fig. 3: World production of the most important vegetable oils in 2004



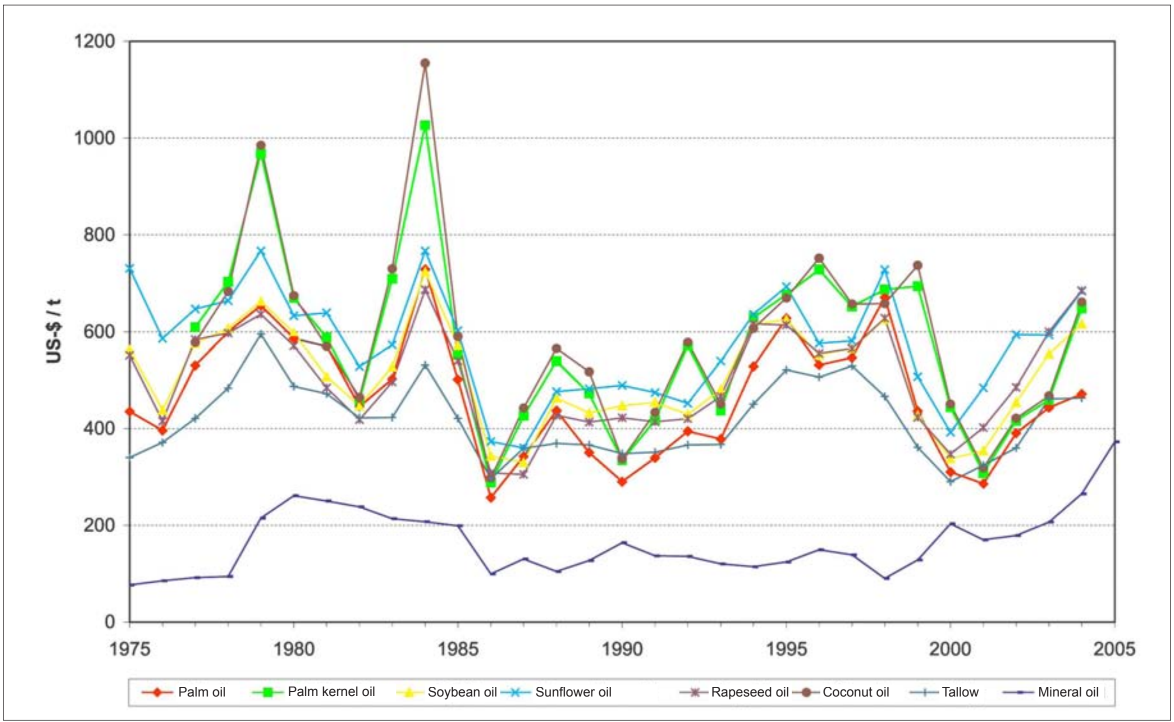
USDA 2006

The prices of the different vegetable oils and vegetable-oil raw materials have had a strong influence on production and world trade over the past decades. The relative stability of vegetable-oil prices in the 1950s and 1960s led to a continuous growth in production and world trade. Following a sharp rise in the 70s and the subsequent volatility of both world market prices and the relation between the different vegetable-oil prices, uncertainty about prices among oil-crop producers increased significantly in the 80s and 90s (Franke 1994).

Producers of coconut, palm and olive oil were particularly hard hit because there is little they can do to respond to short-term fluctuations (see Fig. 4). Particularly striking are the coconut-oil peaks in 1979 and 1984 (caused by El Niño events in 1977/78 and 1982/83) and the related drought-induced crop failures in south-east Asia (Philippines, Indonesia) (MPI 2006).

Fig. 4 shows the prices of different vegetable oils in the period from 1975 to 2005. In the first six months of 2006 (RBD), palm oil cost approx. $450 per tonne, soybean oil approx. $550 per tonne and rapeseed oil about $750 per tonne. No direct connection exists between the prices of vegetable oils and the price of mineral oil, which is also shown. However, there were signs of a link between ethanol made from sugar cane and the price of crude oil, which could also have effects on the price development and profit margins of other biofuels in the future (OECD 2006).

Fig. 4: Average annual prices of different vegetable oils on the north-west-European market.



ISTA Mielke 2004 and mineral oil MWV 2006

2.3 Palm oil as a source of bioenergy

Like other vegetable oils, palm oil can also be used as a fuel for internal combustion engines, both in vehicles and in stationary plants – i.e. power stations, district-heating stations and (block-type) cogeneration plants.

2.3.1 Use as a fuel (mobile)

Although pure vegetable oils are very similar to conventional mineral diesel fuel, several important parameters (e.g. viscosity) differ (see Table 5). As a result, in their pure form they are usually not suitable as fuels for conventional diesel engines. There are two possible ways of adapting them for use in diesel engines: either the diesel engines are modified for the use of pure vegetable oils, or the pure vegetable oils are chemically converted to make their properties very similar to those of mineral diesel fuel.

Two chemical processes can be used to do this:

Transesterification: a reaction product of the transesterification of vegetable oil with methanol is (vegetable-oil) fatty acid methyl esters (FAME), most properties of which are similar to diesel fuel; it is generally referred to as biodiesel. In this process, the vegetable oils are converted using methanol and caustic soda (catalyst), which is neutralized with phosphoric acid after conversion. Glycerine is also produced during transesterification.

Tab. 5: Properties of different vegetable oils and biofuels

	Density (15 °C) [kg/dm³]	Calorific value [MJ/kg]	Calorific value [MJ/l]	Viscosity (20 °C) [mm²/s]	Cetane number	Flash point [°C]	Fuel equivalence [L]
Diesel[1]	0.84	42.7	35.9	5.0	50	80	1.00
Rapeseed oil[1]	0.92	37.6	34.6	72.3	40	317	0.96
RME[1]	0.88	37.1	32.6	7.5	56	120	0.91
Palm oil[1]	0.92	37.0	34.0	29.4*	42	267	0.95
PME[2]	0.88	-	-	4.4**	58	182	-

* Viscosity at 50°C **Viscosity at 40°C [1] FNR 2005 [2] Cheng et al. 2005

Hydrogenation: in the VEBA process, vegetable oil (about 10%) is blended with crude oil before it is processed to diesel fuel. After the hydrogenation processes, the vegetable oil is almost identical to the diesel fuel. The newly developed NExBTL process (NESTE OIL 2006) is also based on the hydrogenation of pure vegetable oils or animal fat.

Vegetable-oil fuel

In order to be able to use pure vegetable oil as a fuel it is necessary to adapt the diesel engine‘s combustion technology to vegetable oil‘s typical properties (high viscosity, different ignition and combustion behavior). Engine systems specially developed for vegetable oil, such as the Elsbett engine, have been successfully tested over the last two decades in cars, trucks and tractors.

Apart from diesel engines that are specially designed for vegetable-oil fuel, it is also possible to adapt series diesel engines and their periphery to vegetable oil operation (e.g. by modifications to the combustion chamber, the injection nozzles and injection electronics). Such methods have recently been becoming more popular than special engines.

Poor fuel quality has often been the main cause of breakdowns. A legally binding standard (DIN V 51605) for the production and marketing of rapeseed oil as a fuel has been in force since the beginning of July 2006.

However, the use of pure palm oil as fuel in Europe involves complex processes due to its high melting point (36-40°C). For example, the fuel tank, lines and filters have to be constantly heated, and special pumps are needed. Companies specializing in converting engines, such as the rapidOil AG from Munich, are currently working on corresponding technical solutions and expect to reach market maturity in 3 to 6 months (Rapidoil AG 2006).

In warmer regions, palm oil can be used as pure fuel or blended with diesel fuel in certain ratios. In Malaysia and Thailand there are efforts to domestically market a blended fuel made up of 5% refined palm oil and 95% diesel fuel (see below).

Biodiesel (FAME)

„Biodiesel“ is the generic term for all types of fatty acid methyl esters (FAMEs) made from different raw materials and used as fuels. They are transesterified vegetable oils that have been adapted to the properties of mineral diesel fuel and can therefore be combusted in conventional diesel engines. In Germany, this term may only be used for fuels that correspond to the DIN EN 14214 standard, which was introduced in 2003.

This standard does not make a direct reference to the kind of raw materials the corresponding fatty acid methyl ester has to be made from. However, limits applying to certain parameters (e.g. oxidation stability, iodine number, content of polyunsaturated fatty acid, coconut residues) indirectly restrict the possible range of raw materials.

Because of its solvent-like properties (limited material compatibility), biodiesel (FAME) may only be used as a pure fuel in approved and/or retrofitted vehicle types. Some vehicle manufacturers, however (e.g. VW, Audi, Skoda, Seat and BMW), have only approved the use of rapeseed oil methyl ester (RME).

Apart from its use as pure fuel, biodiesel conforming to DIN EN 14214 may also be blended with mineral-oil diesel up to a volume of 5% (DIN EN 590) without being specially labeled. This does not require special approval from the vehicle manufacturers, and engines do not need to be refitted.

Biodiesel from palm oil (PME)

Rapeseed oil is the main raw-material basis for biodiesel in Germany. Rapeseed oil is particularly well-suited for the production of biodiesel, since even without additives it has a CFPP figure (Cold Filter Plug Point, filterability limit under laboratory conditions) of between -10 and -12° C and oxidation stability figures of 9 hours and more. It should also be noted that most additives have currently only been tested using RME.

By contrast, biodiesel made of raw materials with a high content of saturated fatty acids (e.g. from palm oil or animal fats) performs poorly in cold conditions. There have been repeated reports of filters being blocked by palm oil methyl ester blends, causing problems for users and gas stations. For chemical-physical reasons, it currently seems unlikely that additives will make it possible for enable methyl esters with very low CFPP figures (e.g. palm oil methyl ester (PME) or blends containing substantial proportions of PME) to be used in northern winters in a way that conforms with DIN EN 14214 (AGQM 2006).

Efforts are currently being made at the European level to change the DIN EN 590 diesel fuel standard so that the added biodiesel does not have to comply with the low-temperature properties (CFPP figure) required by the biodiesel standard DIN EN 14214. Such a blended fuel could then be made suitable for winter use with suitable additives (based on a maximum biodiesel share of 5%). This would open up the European biodiesel market for PME.

Because of a lack of statistics it is not known to what extent PME is already being used in the trucking business (high cost pressure). The Arbeitsgemeinschaft Qualitätsmanagement Biodiesel e.V. (biodiesel quality management working group, AGQM) expressly points out, however, that any damage caused by poor fuel quality (e.g. failure of components in the fuel-supply or exhaust-treatment systems) will not be covered by manufacturer warranties.

Despite the remaining technical and legal uncertainties, the first major investments and planning projects are currently underway in Europe. In Zwijndrecht, the Netherlands, a joint venture involving Golden Hope Platations Bhd and Godiver Handelsgesellschaft mbH is planning a 30,000 tonne biodiesel plant, and in Northern England Biofuels Co. Plc will shortly be commissioning a 250,000 tonne plant to produce biodiesel from palm oil (among other things) (F.O. Licht 2006).

2.3.2 Use as a fuel (stationary)

In principle, fatty acid methyl esters (FAME) can be used as a fuel in the same burners as heating oil. However, pure vegetable oil is normally used for stationary applications in power stations, district-heating stations and (block-type) cogeneration plants. For example, vegetable oil can be used in modern plants instead of heating oil (extra light) if the oil is preheated, or else it can be blended (10-20%) with light heating oil in a „hot combustion chamber“ (particularly in small heating systems). By contrast, all heavy-oil burners with rotation/pressure atomizers and oil pre-heating systems (50-60°C) can be operated with pure vegetable oil without the addition of heating oil (especially large heating systems). Furthermore, it can be used without problems in burner types that are suitable for vegetable oils (Hartmann & Kaltschmitt 2002).

In thermal power stations, palm oil is combusted to produce steam. The latter‘s thermal energy is first converted into mechanical energy by a turbine, and this, in turn, drives a generator which converts it into electrical energy (electricity).

Pure palm oil is especially suitable for plants that otherwise burn heavy heating oil. Due to its high melting point (see above), the use of palm oil involves a certain amount of additional effort (heating), although enough process heat is usually available.

In Europe, approx. 1-1.5 million tonnes of palm oil was used in power stations in 2005, compared to total imports of palm oil amounting to 3.5 million tonnes. About a third of this was supplied by the Dutch company Biox B.V. (Kerkwijk 2006). Starting in 2007, Biox will be supplied by IOI Group Bhd and Golden Hope Plantations Bhd (both based in Malaysia) and intends to build another four palm oil-based power stations in the Netherlands. In 2005, an estimated 400,000 tonnes of palm oil was used for power generation in the Netherlands alone (F.O. Licht 2006).

3 Future demand for palm oil and politics

by Andreas Pastowski

Adding together the use of palm oil as an energy source and all other uses, the Food and Agriculture Organization expects palm oil production to double between 1999/2001 and 2030 (FAO 2006b).

For the future, the following are likely to be the most relevant factors determining global output and the uses to which palm oil is put:

- The development of the population, per-capita income, consumer habits that determine global demand as a whole, and the demand for individual products in the energy and non-energy fields.

- The price of crude oil, which is an important determinant of the use of vegetable oils as an energy source.

- The overall political conditions relating to the cultivation, export and use of oil plants and the products made from them, and especially relating to their use for energy purposes in the transport and energy sectors.

Potential global area of cultivation

Exact predictions on the further development of the energy-related palm oil market are impossible to quantify. This is due to marked price fluctuations, particularly in the agricultural sector, and uncertainty on the crude-oil markets. Furthermore, the palm oil market depends on subsidies and tax benefits in the main importing countries like the EU, as long as there is no consistent global allocation of carbon emissions to all energy sources. Thus, data are only available on the policies governing the promotion of renewable energies. Here too, however, none of the decisive parameters have been cast in stone – e.g. how should biofuel‘s share of total fuel consumption be divided among rapeseed-oil biodiesel, palm oil biodiesel and ethanol. Global or country-specific consumption estimates in the form of extrapolations based on demographic or economic developments represent another quantifiable – albeit not very reliable – parameter.

3.1 Prospects of the palm oil market

In the past, the global demand for vegetable oils has primarily depended on its use in the production of foodstuffs and cosmetics. In many of its applications, palm oil faces intense substitution competition from other vegetable oils whose respective output can be varied within much shorter periods; as a result, volume and price fluctuations are passed on to palm oil via substitution mechanisms. Such a market situation is marked by big fluctuations in the sales and yields of the agricultural production companies and the number of jobs they offer.

In the countries where the most oil plants are grown – unlike the EU – there are hardly any subsidies aimed at evening out fluctuations in the agricultural field. Against this background, any prospect of opening up additional markets offers considerable potential for steadying the supply and prices of oil plants, sales, export income and related employment figures. This applies all the more to the energy markets, because in the future these will be marked by major increases in demand and a growing structural lack of affordable fossil fuels.

The advantages of more diversified sales markets became particularly evident following the establishment of a market for bioenergy directly related to sugar-cane cultivation and the combined production of sugar and ethanol in Brazil. The growing use of rapeseed oil as an energy source in the European Union could be an explanation of why the fluctuation margin of the annual average prices of vegetable oils has been declining since the mid-eighties and the price corridor of the various vegetable oils has also been narrowing. The economic advantages of growing oil plants for the combined production of vegetable oils both for traditional uses and as an energy source therefore represent a strong economic incentive to expand the cultivation of oil plants, even at the expense of other crops that do not have this advantage.

Both the development of the crude-oil price and the demand for vegetable oils will be determined in the future by global population growth and the increasing per-capita income in many regions of the world. This will also affect today‘s main oil-palm-growing countries. Both factors suggest the likelihood of a marked increase in the demand for palm oil both for traditional and for energy-related uses. Especially in the main countries where the crop is currently grown, this could lead to more of their output being covered by domestic demand, which might limit future export potential.

In the case of ethanol, a link has been discovered with the price development of mineral crude oil. If there is a similar tendency in the case of palm oil, non-subsidized palm oil would hardly be marketable after a foreseeable period of time, since the higher profits would be eaten up by the even-faster-rising agricultural production costs based on the price of crude oil (OECD 2006). In the view of Malaysian analysts, the profit limit has already been reached, despite the currently high crude-oil price of over $60 a barrel: crude palm oil must not cost more than $430 a tonne if it is to remain profitable, as production costs calculated on the basis of the crude-oil price rise more quickly by comparison, and it already reached a price of $426 in July 2006 (Star Publications 2006).

It seems difficult to fix a scientifically justifiable lower profit limit for vegetable oil relative to fossil fuel, i.e. the crude-oil barrel price at which palm oil become profitable. When the crude-oil price rises, the cost of fertilizers also rises, among other things, so that the production cost of palm oil is also affected. On the other hand, more money can then be made with non-energy palm-kernel oil, because the fossil tenside that is substituted will also go up in price, i.e. there are opposite and feed-back effects.

What makes the calculation more difficult is the fact that rising crude-oil prices also make alternative fossil petrochemicals in the mobile sector more attractive, i.e. a switch to biodiesel is not inevitable. In the field of stationary fuels, finally, vegetable oils can also be substituted by coal or uranium (Reinhardt 2006).

Because of its high output per unit of area and the further diversification of the sales markets as a result of its use as an energy source, palm oil is an economically attractive agricultural product for the growing countries. For a number of reasons, today‘s production is largely concentrated on Indonesia and Malaysia, although this does not exclude the possible existence of even greater potential in other equatorial regions. Palm oil offers importing countries a chance to overcome the limits of their own production potential and in some cases to use cheaper palm oil produced with less subsidies to meet their targets for the use of biogenous fuels. Producer countries, by contrast, can substitute crude oil with their locally produced biodiesel and thus make balance-of-payments savings.

After all, in their present stage the markets for palm oil as an energy source in the importing countries are artificial markets; they import palm oil primarily because the biodiesel made from it is the subject of tax breaks aiming to protect the climate and encourage the use of renewable energy sources. However, the extent of tax benefits is the subject of discussion, along with other political ideas aimed at increasing the use of biogenous energy sources. In Germany, the system of compulsory blending (with gasoline and diesel) to be introduced on 1 January 2007 will increase demand for biofuels and thus for vegetable oils even more than tax breaks, since this has to be carried out independently of the costs, and higher costs can be passed on more easily via the large quantities of the fuel blends. Politics is thus currently the main determinant of the demand for palm oil for energy purposes.

In the long run, therefore, we can expect a considerable expansion in the use of palm oil as a source of energy: over the total prediction period up to 2050, the Food and Agriculture Organization FAO predicts an annual growth rate of 3.2% for the non-food sector, compared to only 1.5% for the food sector. Total palm oil consumption in 2030 is put at 54.2 million tonnes of oil content equivalent compared to 25.6 million tonnes in 2001 (FAO 2006b).

3.2 EU policy on biofuels and its implementation

The Green Book „Towards a European Strategy for the Security of Energy Supply“ (CEC 2000) emphasizes the importance of alternative fuels for the security of supply, their possible contribution toward reducing greenhouse-gas emissions and the potential offered by fallow biomass. The report accompanying the Green Book estimates that, if suitable basic conditions are created, alternative fuels as a substitute for gasoline and diesel fuels can reach a 20% share by 2020 (CEC 2002).

Two proposals were made on directives in the wake of the Green Book in June 2001: on the one hand, the member states would be committed to certain quantity targets on sales of biofuels in the period from 2005 to 2010; on the other, they should be given an opportunity to broaden the hitherto narrow framework for granting tax benefits for biofuels (CEC 2001a, 2001b, 2001c). The „Directive of 8 May 2003 on the promotion of the use of biofuels or other renewable fuels for transport“ (CEC 2003a) aims at increasing „the use of biofuels or other renewable fuels to replace diesel or petrol for transport purposes in each Member State.“ The member states are to ensure that biofuels and other renewable fuels reach a specified minimum share of their markets and should lay down corresponding benchmarks. The suggested reference values for these benchmarks are a 2% share (measured by energy content) of all gasoline and diesel fuels for the transport sector put into circulation on their markets by 31 December 2005, and a 5.75% share by 2010. This EU Directive simultaneously lays the foundation for the national policies in the Netherlands and Germany examined below. EU policies also have a certain orienting influence on Switzerland.

In the White Paper „Energy for the Future: Renewable Sources of Energy“ (CEC 1997), reference was already made to the need to expand biofuels‘ share of the market and to the fact that prices were not competitive without supporting measures. The Commission‘s first proposals on the introduction of tax benefits in the EU member states date from this time. The „Directive of 27 October 2003 on restructuring the Community framework for the taxation of energy products and electricity“ (CEC 2003b) makes it possible for the member states to grant tax benefits on fuels produced from renewable raw materials and on biomass products – right up to full exemptions.

Three EU member countries (Austria, Slovenia, Czech Republic) set themselves more ambitious targets for the market share of biofuels for 2005; however, the targets of most member states are well under the 2 percent envisaged by the EU. This may be because the market shares of biofuels in 2003 were for the most part well below 2 percent and in some cases around 0 percent. The EU target of a 5.75 percent share for biofuels by 2010 is thus quite ambitious.

Although it should be taken into account that the target can be partially met by the production and blending of ethanol, and that not all countries have to make an equal contribution to reaching the target, the gap is nevertheless clearly recognizable. The question is how it is to be filled. This suggests that the EU target might be partly reached by importing vegetable oils. The low market shares up to now indicate that there has been little or no production capacity and infrastructure for the production of vegetable-oil-based biodiesel or ethanol in the corresponding member states. Since building up such production capacity takes time, there is a tendency to switch to imported biofuels. Biodiesel made from rapeseed oil currently has a market share of approximately 85-90% of EU biodiesel consumption; FEDIOL, the European oil-mill federation, expects exclusionary effects in favour of an approx. 20% market share for palm oil biodiesel. Another decisive factor apart from the lack of refinery capacity which has been pushing up the demand for imports is the rising price of rapeseed oil caused by keen competition from the use of rapeseed oil as a foodstuff (Krishna & Mudeva 2005).

Up to now, palm oil has not been relevant as an alternative energy source within the framework of the Clean Development Mechanism (CDM); the number of CDM projects involving palm oil production is still small, even though they can help improve the greenhouse gas balance. This is evidently a result of the general methodological difficulties of implementing CDM projects in the transport sector, which also affect alternative fuels. Furthermore, CDM projects with palm oil as an alternative source of energy can only be implemented in potential CDM host countries, which excludes the countries of the EU.

3.3 Policy on biofuels in the Netherlands

In March 2006, the Dutch government set programmatic targets according to which biogenous fuels should make up at least 2 percent of combined gasoline and diesel sales by 2007, and 5.75 percent by 2010 (VROM 2006). This corresponds exactly to the EU target with the exception of the later target year of 2007. Another aim is to ensure a minimum of sustainability in the production of biofuels by excluding fuels whose production involves extensive deforestation, for instance. To this purpose the government of the Netherlands intends to initiate a corresponding certification system at the EU level.

It was announced at the same time in the Netherlands that tax incentives worth two percent would be introduced in the course of 2006 in order to reach the share of biofuels envisaged for 2007. Furthermore, the Dutch government intends to provide €60 million between 2006 and 2010 to promote innovative projects in the field of alternative fuels, in order to exhaust market potential as far as possible and maximize CO_2 reduction. This almost exactly mirrors the EU targets; a simultaneous aim, however, is to ensure that imports of biogenous energy sources do not have negative environmental consequences and to establish an EU-wide framework for this. It will remain to be seen whether the introduction of an EU-wide certification system at the initiative of the Dutch government will succeed and an effective contribution can be made toward protecting the rain forests. Due to the Netherlands‘ geographical position, with its large sea ports and refineries, it can be expected to be the primary route for importing palm oil into the EU market because of the favourable logistics.

3.4 Policy on biofuels (bioenergy) in Germany

At the end of 2004, the Federal German Government adopted a new fuel strategy as part of its first progress report on the strategy of sustainability (Presse und Informationsamt der Bundesregierung 2004). Starting from an approx. 1.2 percent share for biofuels in 2003, the targets set by the EU are expressly confirmed as national objectives. The expectation is that biodiesel and bioethanol will play a major role in reaching the targets by 2020, particularly as admixtures blended with conventional fuels. However, restrictions are expected caused by a domestic lack of land and competition from other forms of use that make a greater contribution to climate protection. Therefore 5 per cent is assumed to be a plausible combined share of biogenous fuels with diesel and gasoline (Arnold et al. 2005).

The Federal Republic of Germany has made use of the „EU Directive restructuring the Community framework for the taxation of energy products and electricity" (CEC 2003b) for biofuels; the government received confirmation of this from the Commission on 18 February 2004. The original intention in Germany was to exempt biofuels from mineral oil tax by 2009. Tax exemption for biofuels has been abolished because of the budgetary situation, the growing demand for biofuels, the EU's ambitious targets, and the shortfalls in tax revenue that have already been experienced or are expected in the future.

The German Bundestag (lower house of parliament) passed several changes in July 2006. Pure biodiesel has been taxed at a rate of 9 euro cents per liter since August 2006. From 2008, the tax will rise by 6 cents a year to 45 cents per liter by 2012. Pure vegetable oil, however, will remain tax-free up to the end of 2007; starting in 2008 it will be taxed at 10 cents per liter. Tax rates for vegetable oil will also rise every year by up to 45 cents per liter from 2012 and thus approach the full tax rate of 2.04 cents per liter. By contrast, pure biofuels used in agriculture and cogeneration plants will remain tax-free. Because the tax does not distinguish between either the types of raw material used or their origins, it has the same effect on all vegetable oils. Since the costs of biodiesel vary considerably, depending on the vegetable oil used, and the tax eats up most of the price advantages compared to mineral-oil-based fuels, a growing trend towards cheaper imported vegetable oils for biodiesel production must be expected in the future.

As far as further developments are concerned, much will depend on the compulsory blending scheme announced by the federal government. The Ministry of Finance has proposed a biodiesel blending quota of 4.4 percent in energy terms or 5 percent in volume terms starting on 1 January 2007. This corresponds to approximately 1.5 million tonnes of biodiesel, or about half of German biodiesel manufacturers' output. The Biofuel Quota Act also empowers the government to enact an ordinance in 2007 setting ecological criteria for the exclusion of imported vegetable oils from blending. These include criteria relating to the principles of sustainable cultivation, demands for the protection of natural habitats as well as for CO_2 reduction.

Another potential subsidy method in Germany whose importance for palm oil is yet to be clarified is the idea of promoting electricity generated from biomass using cogeneration plants. With annexes/plants up to 50 kWel it is assumed rapeseed oil will also be in the future the most important source of energy (IE et al. 2005, S. 57). With plants in the capacity range above 500 kWel increasing their market shares, there is likely to be greater interest in the use of soybean oil and palm oil; in the future, market shares are expected to shift accordingly in favour of these vegetable oils. However, some grid operators are refusing to grant the „renewable resource bonus" (NawaRo-Bonus) of 4 to 6 cents per KWh for electricity generated in stationary cogeneration units using vegetable oils from abroad. The background is that the Renewable Energies Act (EEG) does not unequivocally classify vegetable oils as renewable resources. Up to final clarifying of this legal question and because of the importance of the NawaRo bonus for the operational efficiency of the unit, the use of the imported vegetable oils is currently afflicted with uncertainties in such plants (IE et al. 2005, S. 59).

With its North Sea and Baltic Sea ports, Germany is in a good logistical position to use imported vegetable oils. Current projects for expanding the capacity for the transesterification of vegetable oils are considering Emden or Rostock, among other locations, and a technical design that is flexible enough to use various different vegetable oils. The reduction of tax benefits will intensify the search for more economical vegetable oils for the production of biodiesel than the rapeseed oil that has predominantly been used up to now. Furthermore, compulsory blending will encourage the major mineral oil corporations and their central purchasing departments to get more involved, and this could well mean that cost advantages will be more systematically exploited in the future, leading to higher import shares.

3.5 Policy on biofuels in Switzerland

As a non-EU country, Switzerland does not have to take a position on the EU's targets. Up to now, Switzerland has only announced the qualitative objective of making greater use of alternative fuels in the future. There are also pilot projects testing the practicability of alternative fuels involving vehicle fleets. Switzerland is expected to clarify its objectives and strategy on the future use of alternative fuels in the course of an ongoing legislative procedure on tax exemptions for environment-friendly fuels. It is currently unclear how imported vegetable oils will be handled in this context (BUWAL 2006).

Switzerland currently plans to amend the law and introduce tax benefits for environment-friendly fuels. To this purpose, on 3 May 2006 the Federal Council passed a draft law amending the mineral oil tax law (EFD 2006). Assuming it is confirmed by the Federal Assembly in the autumn or winter of this year, the law will provide for tax incentives for environment-friendly fuels from mid-2007, with the aim of lowering CO_2 exhaust levels in road transport. The reduced tax incomes to be expected from this are to be completely offset by a correspondingly higher tax on conventional fuels. The bill provides for a tax exemption for „fuels from renewable raw materials," i.e. fuels manufactured from biomass or other renewable energy sources. The Federal Council will define fuels from renewable raw materials in terms of their contribution to environmental protection. This definition could include minimum requirements relating to the overall ecological balance (Entwurf Änderung Mineralölsteuergesetz (Draft Amendment to Oil Tax Law) 2006). Depending on how these are structured, they could become a criterion for the exclusion of certain vegetable oils.

Even though there is no official target figure for the use of biogenous fuels, Switzerland will take a top position in the promotion of biofuels if this amendment is passed by the Federal Assembly. The complete exemption of biofuels from mineral oil tax and the compensation of the shortfall in government revenue by an increase in the tax rates for mineral oil products could represent a very strong financial incentive to use biogenous energy sources in transport. This would primarily apply to the use of pure biodiesel and vegetable oils; as far as the blending of biodiesel is concerned, the tax effects would balance each other out because of the way the law is structured, which could lead to an indifferent attitude toward blending in the petroleum industry from the tax perspective.

In Switzerland, the economics of using imported vegetable oils (e.g. palm oil) to produce biodiesel is burdened by higher transport costs, since the country has no sea port (like the Netherlands or Germany) from which to supply the immediate hinterland. This makes longer overland and in some cases alpine transport journeys necessary. To this extent it is uncertain whether the higher transport costs can be offset by the lower product prices and whether imports of palm oil for energy purposes can really be expected to increase in Switzerland.

3.6 Policy on biofuels in the palm oil producer countries

Malaysia is forging ahead with the domestic introduction of a blended palm oil fuel made up of 5% refined palm oil and 95% diesel (MPIC 2006). Parallel to this, there are plans to start producing a total of 180,000 tonnes of PME (biodiesel) this year at three sites – exclusively for export to Europe and other regions (F.O. Licht 2006). Altogether there is a capacity of approx. 1 million tonnes of PME planned (F.O. Licht 2006)

Indonesia already hopes to earn $1.3 billion from exports of biofuels by 2010 and intends to build or expand 11 refineries for this purpose. Since May 2006, diesel within Indonesia can also contain up to 10% of biogenous fuel. Together with Malaysia, Indonesia has decided to reserve 40% of palm oil exports for biofuels. 3 million hectares of land are to be additionally prepared for palm oil production. In Malaysia the palm oil production is to be increased from 11.8 to 18.8 million tonnes by 2020, which would extend the managed surface from currently 3.5 million hectares to 5.1 million hectares. (Thukral 2006b and Star Publications 2006).

Apart from ecological problems, issues like weak governance and poor enforcement of regulations in Indonesia could make it difficult for the country to raise the US$ 22 billion needed from investors for the expansion of its oil palm refinery capacity (Kleine Brockhoff 2006).

Furthermore, in Indonesia, weak governance and unclear regulations also lead to unregulated or the transformation of natural forest, that is illegal or legal but not necessarily good for the environment. Due to the political reforms implemented since the fall of the

Suharto regime in 1998, decentralization has given more power to the provincial governments. They in turn are also susceptible to irregular and bad practices at the local level when granting licenses to use land classified as „degraded natural forest." (Kleine Brockhoff 2006).

3.7 The framework of international palm oil trade

At present, the amount of raw materials available in the EU member states alone will not be enough to enable the EU to meet its targets on the use of alternative fuels. It is also uncertain whether it will be possible to reach the targets solely on the basis of potential output in the member states in the future. 1.19 million tonnes of rapeseed was imported into Germany in 2002/2003, for example. 68% of this came from France and another 16% from the Czech Republic. In the same period 740,000 tonnes were exported to the Benelux countries (Belgium, Netherlands and Luxembourg) as well as to Great Britain and Mexico (Thraen et al. 2004, S. 83).

It is currently unclear to what extent the EU can achieve a high level of self-sufficiency in alternative fuels in the future by processing residual biomass and waste products as an energy source, since this method is only just getting started. The predominant use of oilseeds for the production of biodiesel in the EU has already pushed prices up, especially for rapeseed oil. Since in principle any vegetable oil can be used as the energy source (either direct or after processing into biodiesel), the increase in rapeseed oil prices provides an incentive to use other (perhaps imported) vegetable oils or biodiesel made from them. Thus, the use of biomass as an energy source can stimulate trade both in the corresponding raw materials and in the energy sources derived from them. This development has clearly already taken place in the case of ethanol; its raw products cannot be transported, but ethanol itself is internationally traded in considerable and increasing quantities in the meantime.

The trade in vegetable oils can be limited for technical reasons if the raw materials required to produce biogenic fuels are too bulky or perishable to be transported over large distances. In the use of palm oil as an energy source, both the unprocessed raw product (palm oil) and the biodiesel which is made out of it can be traded internationally, since the raw product also keeps well and there are only insignificant differences in the transport costs.

There are currently two parallel trends in vegetable oils which might affect the amounts of palm oil imported by EU member states.

Transesterification plants for processing vegetable oils are being planned in the exporting countries. They can extend the value chain in the producer countries, raising economic utility. It is then biodiesel that is exported, if it is not used domestically; income from exports will be correspondingly higher. Malaysia, however, has already announced a moratorium on licenses for palm oil transesterification plants until the government is convinced that the use of palm oil as an energy source will not lead to restrictions on its use as a foodstuff (Thukral 2006).

There are isolated plans to build transesterification plants to process imported vegetable oils into biodiesel near ports in certain EU member states. The plants are being designed in such a way that all kinds of vegetable oil can be used. Parallel to this, some long-term supply contracts are being concluded with the producers in the growing countries to ensure reliable supplies of the raw material at stable prices and quantities.

The EU is pursuing a two-pronged and in some ways rather contradictory strategy in this context. On the one hand, the EU wants to take the interests of its domestic producers and their trading partners into account in the further development of the trade in vegetable oils. On the other hand, there are plans to change the „biodiesel standard" EN 14214 to make it possible to use a broader range of vegetable oils to produce biodiesel (CEC 2006a).

The international trade in palm oil for the production of biogenic fuels is subject to the general WTO regulations on trade in agricultural products. It would be difficult to monitor any special treatment of agricultural products that are used exclusively to produce energy sources, because the decision on use is not taken until the oil arrives in the importing country. The situation is different in the case of palm oil that has already been processed to biodiesel in the growing country, since use as an energy source is the only option in this case. However, it is not clear whether it is possible to trace back to the primary material after it has been converted to biodiesel or whether the real origins might be concealed.

The EU specifies uniform tariff rates via the TARIC (Integrated Tariff of the European Communities). Currently, no import duties are levied on crude palm oil for technical and industrial use (with the exception of the production of food for human consumption) that is imported from Malaysia and Indonesia, the main countries where oil palms are grown. Since biofuels are currently not monitored separately by the customs authorities, it is impossible to determine the respective shares of ethanol, oilseeds and vegetable oil imports used in the transport sector. The EU Commission intends to examine the advantages and disadvantages – as well as the legal consequences – of formulating its own commercial-law nomenclature code for biofuels (CEC 2006a).

3.8 Conclusions

The implementation of the EU‘s policy of promoting the use of biofuels involves major challenges for the member states. In view of limited production capacity and the lower cost of imported vegetable oils as a raw material for producing biodiesel or for stationary use as a fuel, there is a growing tendency to switch to imported vegetable oils. The EU supports this by waiving import duties on palm oil imported for technical and industrial non-food use from the main producing countries Malaysia and Indonesia.

With many member states still busy creating a national framework for implementing the EU targets on the use of biofuels, few of them have confronted the issue of imported vegetable oils and the related potential risk of ecological side-effects. In Switzerland, the situation is on the one hand less favourable, because there has evidently been little in the way of profound discussion on biofuels up to now, and a strategy on the issue is yet to be formulated. On the other hand, there is an intense discussion on palm oil as a raw material for the foodstuff and cosmetics industry which has advanced to the stage that the Migros group has set standards for palm oil suppliers. The government of the Netherlands is examining various tax benefit options and at the same time putting forward the most far-reaching proposal on EU-wide standards on the ecological effects of imported vegetable oils. The German government is striving to meet the EU targets. Policy is currently moving away from tax benefits for biofuels to compulsory blending with mineral fuels. The government is to enact an ordinance in 2007 excluding types of biomass whose production violates the principles of sustainable cultivation or the protection of natural habitats.

This situation in the European importing countries contrasts with the ambitious economic-development objectives of the countries where oil palms are grown – and with the WTO‘s efforts to liberalize the trade in agricultural goods; here, the emphasis is on economic-efficiency gains, and ecological demands relating to the production of agricultural goods are generally perceived as a novel form of non-tariff trade barrier.

4 Environmental effects of palm oil production

by Guido Reinhardt, Nils Rettenmaier and Sven Gärtner

The production and use of palm oil as an energy source can have a wide range of effects on the environment. These are described in this section taking the following aspects under consideration:

- Consequences of deforestation, in particular the loss of biodiversity and ecosystem services in the natural forests cleared for oil palm plantations; possible alternatives to the clearing of natural forests.

- Comparison between the entire chains of production and use of palm oil biodiesel on the one hand and conventional diesel fuel on the other; comparison between the corresponding life cycles from pure palm oil to electricity and(or heat generation on the one hand and conventional power generation using fossil energy sources on the other. Energy balances and greenhouse-gas balances are examined as examples on the basis of such „life-cycle comparisons“.

- Other environmental effects directly related to the production and processing of palm oil.

- Optimization potential: overview of the main areas where ecological improvements could be achieved.

- Future hectarage requirements for palm oil grown for energy or non-energy purposes in the main producer countries of Southeast Asia.

4.1 Oil palm plantations and natural tropical forests

As already mentioned in section 2.1, the oil palm only flourishes in the inner tropics, which, for the most part, would be wooded if nature were allowed to take over. These natural tropical forests are characterized by enormous biodiversity and contribute to human welfare by providing ecosystem services.

4.1.1 Biodiversity and ecosystem services

Biodiversity

Biodiversity means variability among living organisms of any origin and covers variety between species (species diversity), variety within species (genetic diversity) and variety of habitat (ecosystem diversity) (UNCED 1992). Species diversity is thus only one aspect of biodiversity, although, for reasons of simplicity, it is generally used as a synonym for all biological variety.

To date, about 1.5 million animal and plant species have been registered and described worldwide, although conservative estimates put the real number of species at between three and ten million. Other calculations estimate the total number of all species as high as 30 to 50 million. The tropical wet forests are the ecosystems with the richest variety of species on the planet. It is thought that 50-75% of all existing species are indigenous to the tropical damp forests; other estimates put the figure as high as 90% (Radday 2006). It is a known fact that species diversity is declining day by day, largely as a result of human activity: the number of species in tropical forests is falling at a rate that is unique in the history of humankind. In the meantime, the speed of extermination is estimated at between 25-150 species a day (Wilson 1995 and Deutscher Bundestag 1990). This is all the more significant because every loss of species diversity is irreversible – unlike other forms of environmental damage, which can at least be partially reversed in some cases.

Species diversity is in turn regarded as one of the fundamental prerequisites of ecosystem stability, since habitats that are richer in species are usually more stable and resilient to outside influences (disturbances) due to their many interrelations and diverse feedback systems. The higher the number of species and reciprocal effects between them, the more effectively can fluctuations be offset.

A high level of genetic diversity is no less important, however, being a crucial factor in enabling species to adapt to changing environmental conditions and therefore for further evolution. In terms of usefulness for humans, the diversity of species in the tropical forests is of inestimable value for breeding working animals and useful plants, as well as for the development of medicines. According to (Myers 1996) the selling value of pharmaceutical products made from tropical forest plants was $43 billion in the industrialized countries in 1985. Up to now, fewer than 1 % of tropical rain-forest plants have been examined to determine their pharmaceutical properties. It is thought that over 1400 species have cancer-inhibiting qualities (Collins 1990). Here, too, there is a danger that this potential will be irretrievably lost as more and more of the tropical forest is cleared; after all, extinct species cannot be „brought back“ again.

The diversity of the ecosystems also contributes directly to human welfare, since they provide services (generally regarded as cost-free), without which human life would be inconceivable and which would have to be provided in some other way if the ecosystems were lost.

Welfare services
Ecosystem functions – i.e. the functions that an ecosystem fulfils for itself and its environment by means of its complex structure – are therefore also referred to as ecological services. This suggests that these functions are regarded as valuable for human beings and for an intact environment. These services are highly diverse: ecosystems regulate the Earth's gas balance, control the climate, produce biomass, regulate the water balance and the water supply, form soils, control erosion and maintain nutrient cycles. By making comparisons with the cost of replacing these services thorough human technology, (Costanza et al. 1997) assessed the monetary value of worldwide ecosystem services (which are generally taken to be free) at $26.6 trillion, i.e. almost twice the global economic product and thus far beyond all value created by human beings. Tropical forests provide a huge number of ecosystem services on a global level (e.g. the Earth's gas balance), a regional level (e.g. climate control) and the local level (e.g. erosion control); their loss would have drastic consequences. Here, too, we can assume that, once destroyed, ecosystems and their functions cannot be restored.

4.1.2 Deforestation

A third of the Earth's land surface, about 3.9 billion ha., is covered by forest. Tropical forests make up approx. 6% of the world's land surface. Only half of the original forest surface that existed about 10,000 years ago is still there today. At least 14 to 16 million ha. of forests disappears on average every year. That's an area about half the size of Germany. 60% of the world's woodland is to be found in the following seven countries: Brazil, Canada, China, Indonesia, Russia, USA and the Democratic Republic of Congo (WWF 2005a). The largest still intact tropical forests are in the Amazon Basin (Brazil), the Congo Basin (Democratic Republic of Congo) and in the Indo-Malayan region (Indonesia, Malaysia, Papua New Guinea).

More forest has been cleared since 1850 than in the entire history of humankind. Human population, however, has also more than quadrupled from 1.3 billion to 6 billion during this period. With a rising population and consumption of timber products on the increase, the pressure on the forest is growing and the amount of woodland per capita is falling. In 1960 this figure was 1.2 ha.; by 1995 it had been cut by half; the prediction for 2025 is 0.4 ha. of forest per capita (Gardner-Outlaw & Engelman 1999).

The causes of the continuing destruction of the tropical forests are many and complex. Like other natural resources, the tropical forests are caught between general structural problems in the countries of the south. These include population growth, poverty, lack of land, global economic conditions and institutional deficits.

In most countries, especially in many developing countries, long-term forest management cannot compete with other forms of land-use. This paradox situation is caused by several distortions in overall conditions, as well as deficits in the timber industry itself. The expected future value of the forest (e.g. as a genetic resource for products) and the current welfare services it provides are not included when the forest's value is calculated (Radday 2006).

The value is measured in terms of the value of timber stocks, the basis of the future value-added in the form of wages and incomes. In this standardized procedure, forest clearing has an exclusively positive influence on the result and is equated with economic development. This effect is intensified by so-called „perverse incentives" – distortions in the form of tax advantages or subsidies for types of land-use that impair the sustainable protection and development of the forest. In the Brazilian Amazon region, such misguided incentives were granted for years to encourage cattle rearing. The biggest destruction of forests there was caused by these incentives.

Similar relationships can be deduced from the history of the plantation and timber industry in Malaysia and Indonesia, palm oil's main production region. In Indonesia in particular, there is a clear link between land-use zoning for large-scale agricultural or forestry projects and the extensive transformation of tropical forest. This development continues unabated to this day, due to the combined failure of governments and the planning and monitoring authorities. The latest example is the so-called „Mega Oil Palm Project," a forest-conversion project covering 1.8 million ha. that was planned on the border between Kalimantan (Borneo) and the neighboring Malaysian states of Sarawak and Sabah. The planning for this project has been redimensioned in the meantime, following protests from environmental organizations (Radday 2006). Estimates by the World Bank predicting the end of the lowland rain forests in

Sumatra by 2005 at the latest, have already been largely confirmed in the meantime (Holmes 2002). Similar estimates by the WWF predict that the lowland rain forests of Kalimantan (Borneo) will disappear by 2012 if deforestation continues at the present rate (WWF 2005c).

The situation described above shows that overall economic and political conditions in the tropical countries producing bioenergetic raw materials could initiate a development that could substantially increase the pressure on the natural forests and practically cancel out any intention of maintaining the forest. The consequence could be a process in which the forest is sacrificed to large-scale agro-industrial projects. This will be explained in greater detail in the following with reference to a major palm oil producing country, Indonesia:

The term forest conversion relates not only to actual clearing, but also to the continuous process of declining forest functions with the intermediate phases of forest degradation and the forest fragmentation, which precede actual deforestation (Kessler et al. 2001).

Provincial governments in Indonesia generally use their five-year plans on land-use to administer the rededication of forest land. The ministry grants these applications on proof of the degradation of the forests. After decades of felling and forest fires on a massive scale, there is a plentiful supply of degraded forests in Indonesia. Government representatives themselves confirm that timber companies leave over 60% of the forest in a run-down condition – and there is a method behind this. As a consequence of the lack of forest declared available for conversion, many companies are stepping up the pressure on the national and also provincial governments to release permanent forest land for conversion into plantation zones, because:

- there is no longer enough forest available for conversion in the better developed western islands, which are closer to the markets; furthermore,
- the conversion of natural forest enables the companies to harvest large quantities of timber either for lumber production or for delivery to the cellulose industry – thus generating fresh capital for follow-up investment.

This pressure has often proved to be effective. 750,000 ha. of woodland that had previously not been classified as forest for conversion was converted into oil palm plantations in the whole of Indonesia up to 1999. 75% of this land lies in Sumatra and 20% in Kalimantan (WWF 2002).

Furthermore, the Indonesian palm oil industry is dominated by groups of companies that also operate in the felling and cellulose/paper-manufacturing industry. It is therefore likely that, after one of the felling companies has used felling rights, a plantation company from the same group will apply for permission to transform the degraded, managed forest – instead of waiting for the forest to regenerate. A new oil palm plantation can start making a profit as early as six to eight years after transformation. By contrast, it would take five to six decades before the felling company could start using the regenerated forest again (WWF 1998).

Fires

An indirect effect of forest clearing is forest fires, which can ultimately destroy a much bigger area of forest than legal and illegal clearing. Slashing and burning is cheaper and quicker for plantation companies than any other method of clearing. Until recently, therefore, „controlled burning“ was a widespread method commonly used by Indonesian plantation companies to clear forests. This involves the removal of wind breaks, the systematic clearing of vegetation and the burn-off of dry plant parts. In windy weather and when the vegetation is dry, however, such „controlled“ fires can quick get out of control. They can spread especially quickly in the managed forests that have been thinned out by felling, because exposure to the sun has dried out the ground vegetation particularly thoroughly here. When wildfires suddenly break out, they also threaten existing plantations and the workers‘ houses.

In general, however, it is very much in the plantation companies‘ interests if forests burn down „by chance“. Even when the fires got completely out of control at the end of 1997, and various bans on the use of fire were imposed by the Indonesian authorities, fire hot-spots were still observed by satellites in areas designated as future palm oil plantations. It is estimated that about 5.2 million ha. of land were damaged by fires in the Indonesian province of East Kalimantan, Borneo, alone during the 1997/98 El Niño season (Siegert 2004).

4.1.3 Social environmental effects

According to PROFOREST, the growing plantation business in tropical regions is not only causing direct environmental damage, it is also destroying the existential economic, social and cultural basis of indigenous subpopulations in particular. The traditionally diverse use of the forest is made impossible and substituted by palm oil monocultures; the people are driven from their traditional settlement areas and/or pushed to the fringes of society. The indigenous peoples' cultural and spiritual lives are also seriously affected, something that cannot be redressed by compensation payments alone.

Conflicts often arise relating to traditional and/or state-attested land rights, which put local communities at a disadvantage because their claims are often not formalized. These groups have frequently already been marginalized in the past and tend to lose out when additional employment opportunities are offered; this is because immigrant workers often have more experience in palm oil cultivation and are therefore given preference over local people.

Palm oil smallholders who supply the plantation companies on their own account or on a contract basis apparently benefit from being tied to bigger plantations, because it gives them a reliable market; other farmers, however, become completely dependent on the large plantation companies, who then dictate the prices.

According to information provided by NGOs, conventions of the International Labor Organization (ILO) have been violated after attempts were made on large plantations to enforce internationally valid rights (such as the formation of trade unions or compliance with industrial safety standards); however, this is denied by the plantation operators (PROFOREST 2003).

4.1.4 Alternatives to deforestation

There are however other ways of preparing areas for oil palm plantations other than the destructive clearing of natural tropical forests discussed above. For one thing, fallow or wasteland areas where natural tropical forests used to stand are very common in the Tropics these days; they could be used for creating new oil palm plantations. For another, existing plantations can be rededicated, as has happened, for example, in the last few years in Malaysia in particular. Many rubber, cocoa and coconut plantations have already been converted into oil palm plantations there.

Planting of tropical fallow land

After repeated fires (or the clearing of natural tropical forests) followed, perhaps, by a brief period of agriculture use, many areas develop into a kind of fallow or waste land, which, in many cases, is overgrown with alang-alang grass (*Imperata cylindrica* (L.) Beauv.). This grass prevents the land from developing naturally into secondary forest and is therefore considered to be particularly problematic.

According to a study by (Otsamo 2001), there is between 8.6 and 64.5 million ha. of alang-alang grassland in Indonesia alone, although this upper limit seems exaggerated. The same study quotes another source that puts the amount of tropical fallow land at 20 million ha. (Holmes 2002) also estimates the figure at several million hectares, (Dros 2003) at approx. 10 million ha.

This degraded land represents an enormous potential and could considerably reduce the pressure on natural forests. These sources provide no information on whether all this land – or part of it – is suitable for oil palm cultivation.

Conversion of other plantations

In Malaysia, where in the meantime oil palm plantations make up 11% of the country's surface area, the amount of land devoted to oil palm cultivation has doubled over the past 15 years. Against this trend (1990-2000: +1.4 million ha.) the total area covered by plantations only increased by about 0.5 million ha. in the same period (Yusof & Chan 2004). Two thirds of the increase thus came from the conversion of other plantations (rubber, cocoa and coconut) (see Table 9).

Tab. 6: Change in the total amount of plantation land in Malaysia 1990-2000 [in thousands ha.]

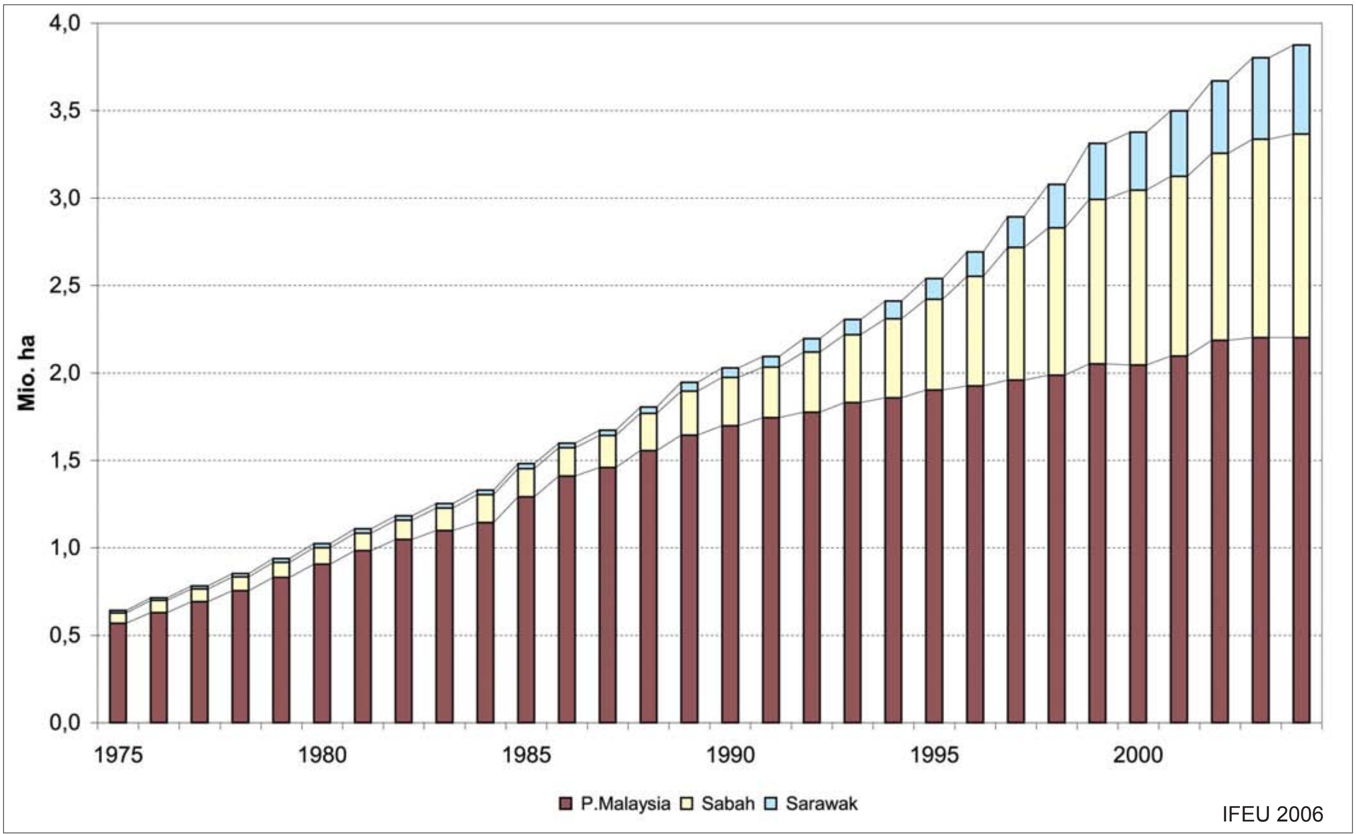
Year	Oil palm	Rubber	Cocoa	Coconut	Total
1990	1,984	1,823	0,416	0,315	4,538
2000	3,377	1,430	0,078	0,108	4,993

Yusof & Chan 2004

Expansion at the expense of the natural forest in Malaysia was carried out in particular in Sabah and Sarawak (see Fig. 5). In Sabah the rate of conversion as oil palm plantations was more than 54,000 ha. per year between 1985 and 2003 (Department of Statistics Malaysia). Assuming – as proposed by various authors – that at least 60 % of this area used to be other 40% consisted of scrubland, rubber, cocoa or coconut plantations, which had to yield in favour of the more profitable palm oil production. No corresponding data is available for Sarawak.

The above observations show that there are alternatives to clearing natural forests when establishing new oil palm plantations. The possible ecological effects of any change in use must, however, be examined before existing plantations are converted. Further research on is concerned (see section 4.2.6). ecological and economic sustainability is required as regards the option of using fallow land

Fig. 5: Increase in the amount of land devoted to oil palm cultivation in Malaysia, 1975-2004



MPOB 2006b

4.2 Palm oil as bioenergy: energy balances and greenhouse gas balances

The use of palm oil as a source of energy is generally regarded as environment-friendly, because at first sight it is CO_2-neutral and saves fossil raw materials, since it substitutes fossil energy sources. This may indeed be the case in some areas, e.g. when palm oil is combusted directly, and exactly the same amount of CO_2 is released as was withdrawn from the atmosphere when the oil palm was grown.

However, if we examine the entire life cycle of palm oil as an energy source – from the production of the biomass to processing and its use to generate energy – we see that the above-mentioned advantages are not necessarily inherent in the system. For example, considerable amounts of fossil energy are often used in the production of fertilizers and pesticides, as well as in plantation management. Furthermore, the use of fossil energy sources involves climate-relevant emissions, so that, if the entire life cycle is included, the CO_2 balance is not automatically neutral from the outset either. Another factor is that CO_2 is only one climate gas among many; we must therefore ask whether even a positive CO_2 balance is perhaps weakened or reversed by other climate-relevant substances. This might be the case, for example, if emissions from the effluent generated in palm oil processing were to release a lot of methane into the atmosphere, or if the clearing of tropical forests to prepare land for oil palm plantations were to release an excessive amount of carbon into the atmosphere in the form of CO_2.

In short, the ecological advantages and disadvantages of palm oil as an energy source cannot be listed and assessed easily; it must be determined very carefully, taking the entire system into account. This can be properly carried out with the help of life-cycle assessments.

4.2.1. Procedure and comparisons examined

Comparisons examined

As already described in section 2.3, palm oil can be used as an energy source in different ways, i.e. in both mobile and stationary applications. The following main uses are dominant in Europe:

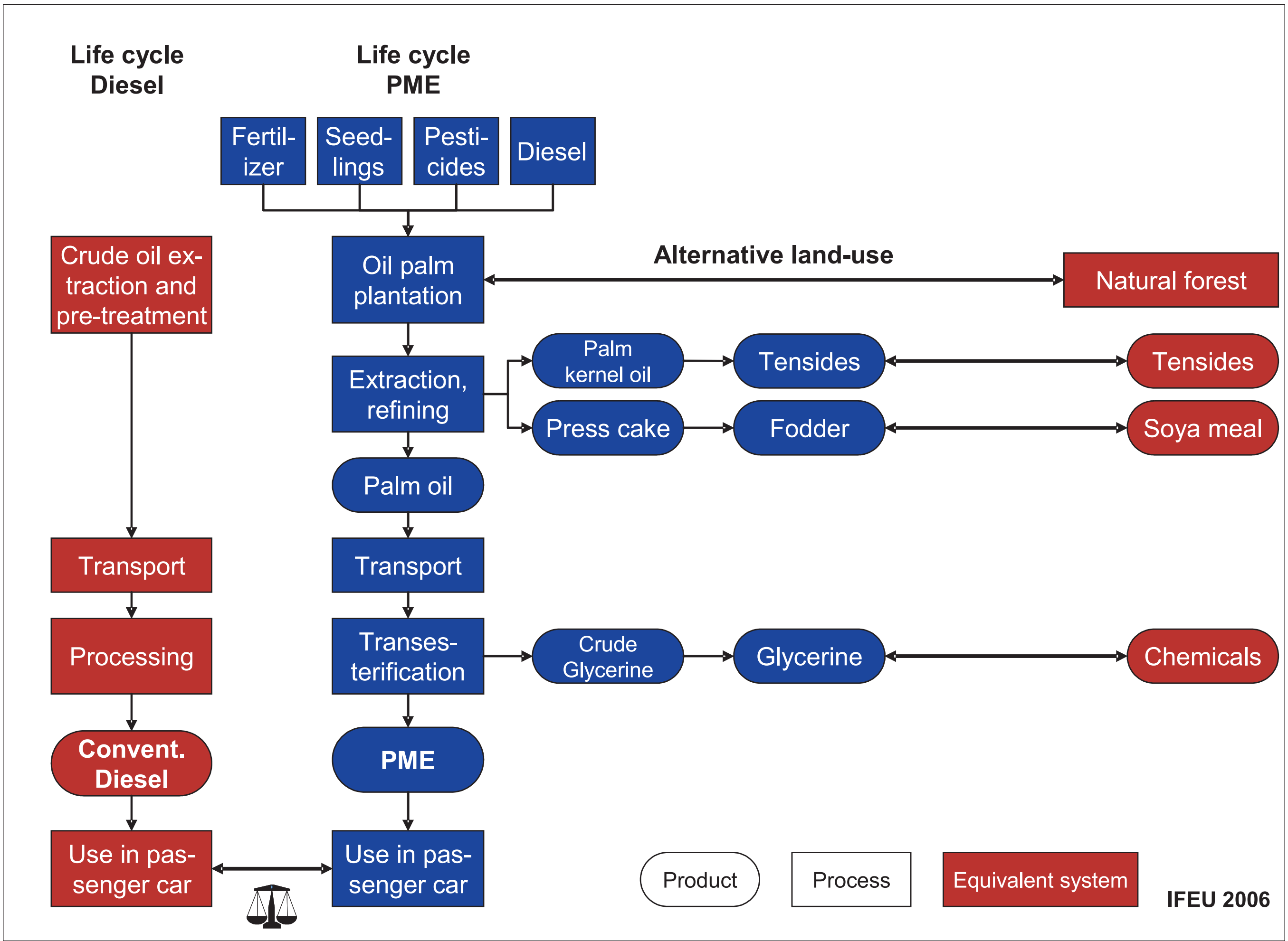
- Palm oil biodiesel, i.e. transesterified palm oil, used as a biofuel in vehicles that run on diesel. Conventional diesel fuel is substituted in this case.
- Pure palm oil in stationary plants for generating electricity, heat or both (cogeneration). Here, different energy sources (natural gas, light fuel oil, etc.) are substituted respectively, depending on which energy sources are used for conventional power or heat generation.

As briefly mentioned above, balances are drawn up over the entire life cycles of both palm oil and the respective conventional energy sources that are substituted by palm oil.

Mobile use

As an example of this, Fig. 6 shows the life-cycle comparison between conventional diesel fuel and palm oil biodiesel (PME). All operating media and by-products are included in the analysis. The latter are credited to palm oil in the balance. In the case of palm oil biodiesel, this involves three by-products. Palm-kernel oil, which is extracted from the seeds of the oil palm, is processed to tensides, substituting mineral-oil-based tensides. The palm kernel cake – the residue left after the seeds are pressed – is used as animal fodder and substitutes for conventional feeds such as soya meal. Furthermore, the transesterification of palm oil to PME produces large quantities of glycerine, which (after processing) can replace chemicals with equivalent uses e.g. in the pharmaceutical and cosmetics industry.

Fig. 6: Life-cycle comparison between conventional diesel and palm oil biodiesel (PME), both used in a diesel vehicle.

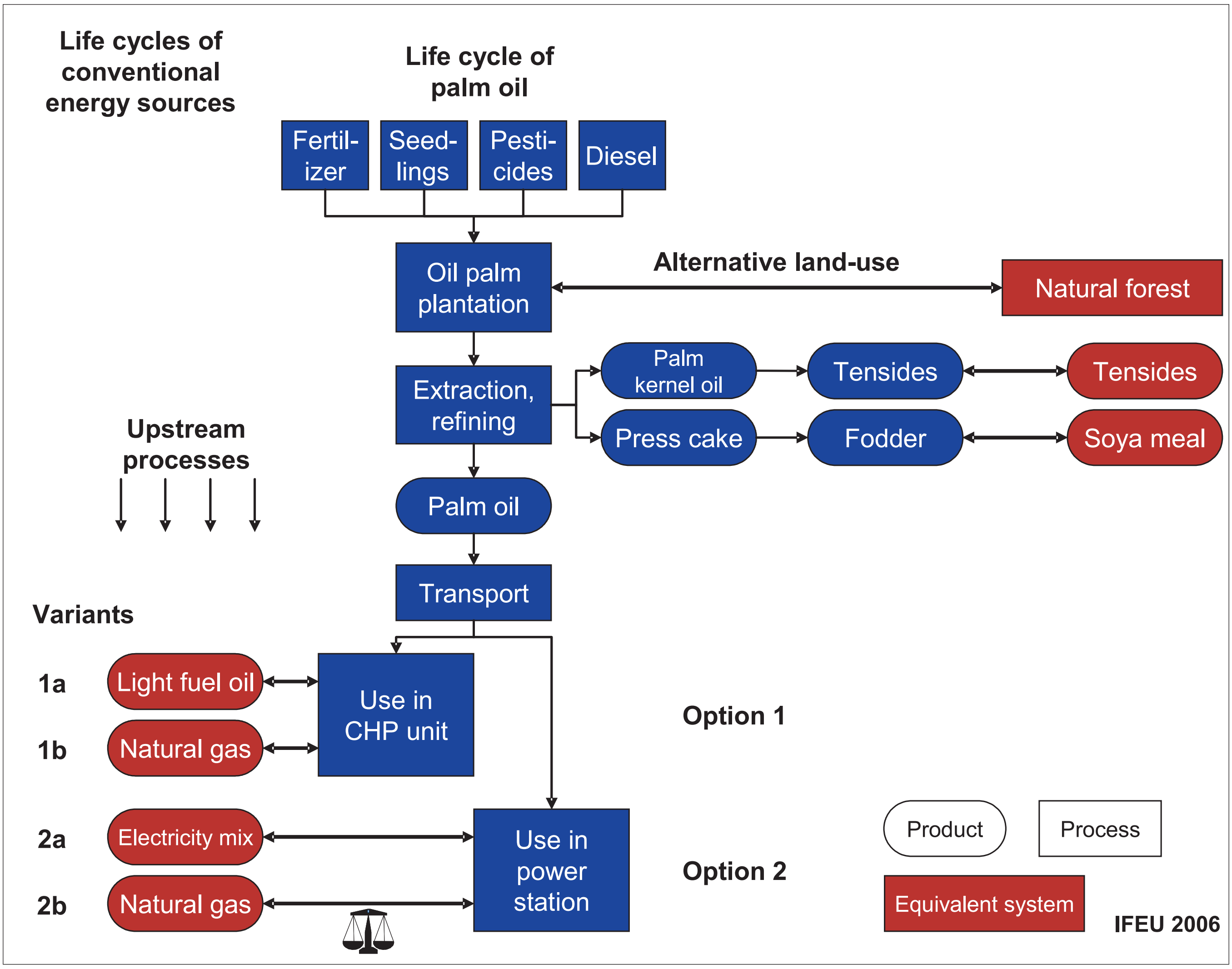


Stationary use

Results vary when palm oil is used as fuel in stationary plants; they depend firstly on whether both power and heat are generated or only power or heat, and secondly on which fossil energy sources are substituted respectively. After all, conventional electricity and heat can be generated in different ways. The following possibilities are considered here (see Fig. 7):

1: Combined heat and power unit (CHP unit): palm oil is used in a CHP unit for the cogeneration of heat and power.
1a: light fuel oil is substituted (LFO-CHP unit).
1b: natural gas is substituted (NG-CHP unit).
2: Power station: palm oil is used in a power station solely to generate electricity.
2a: Electricity from the public grid is substituted (electricity mix).
2b: Natural gas is substituted (NG power station).

Fig. 7: Schematic life-cycle comparisons between conventional energy sources and palm oil used as fuels in a combined heat and power unit (CHP unit) or a power station.

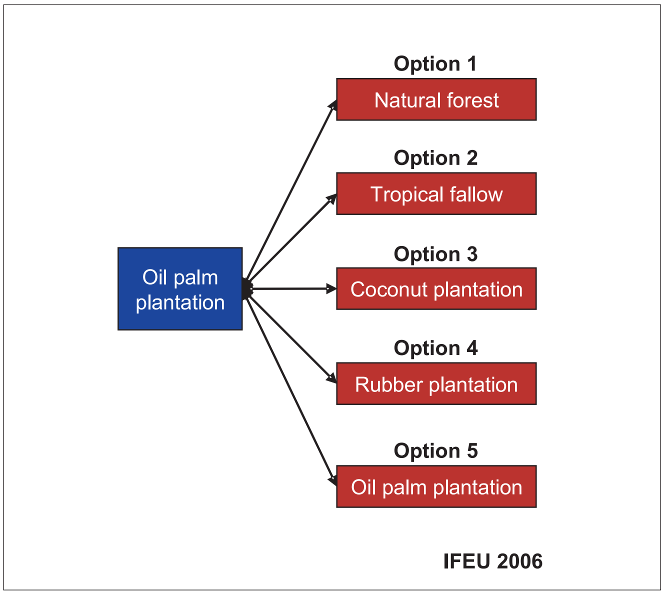


Alternative land-uses

In addition to the alternative land-uses (natural forest) shown in Fig. 6 and 7, there are a number of other options (see Fig. 8). As already mentioned in section 4.1.3, oil palm plantations can also be established on tropical fallow land (option 2) or instead of other plantations. Three options were selected to represent the latter: coconut, rubber and oil palm plantations (options 3-5). In option 5 the use of the palm oil changes from a foodstuff to an energy source (mobile and stationary use).

The options are presented in sequence. Details (in particular on the conversion of other plantation types) can be found in the respective chapters.

Fig. 8: Alternative land-uses



Analyzed environmental effects

Environmental effects (energy savings and greenhouse effect, see Table 7) were analyzed to determine the ecological advantages and disadvantages of using palm oil as an energy source (fuel).

The results shown here come from IFEU's internal database (IFEU 2006). As described, balances are drawn up covering their entire life cycles according to the life-cycle assessment standard (DIN 14040-43). Further details on system cut-off points, boundary conditions and procedures are documented in (Barks et al. 1999 and Reinhardt et al. 1999).

Tab. 7: Analyzed environmental effects

Environmental effect	Description
Energy saving	This test balances what is known as the conservation of resources for the non-renewable energy sources, i.e. fossil fuels such as oil, natural gas, coal and uranium ore. The simpler term „energy saving" is used for the results in the following.
Greenhouse effect	Heating up of the atmosphere as a consequence of human beings releasing climate-affecting gases. The most important greenhouse gas is carbon dioxide (CO_2), which is produced by the combustion of fossil energy sources. Emissions of methane (CH_4) and laughing gas (N_2O) are also measured and converted in weighted form into carbon-dioxide equivalents (CO_2 equivalents) (factor 23 for CH_4, factor 296 for N_2O).

IFEU 2006

4.2.2 Oil palms instead of natural tropical forest

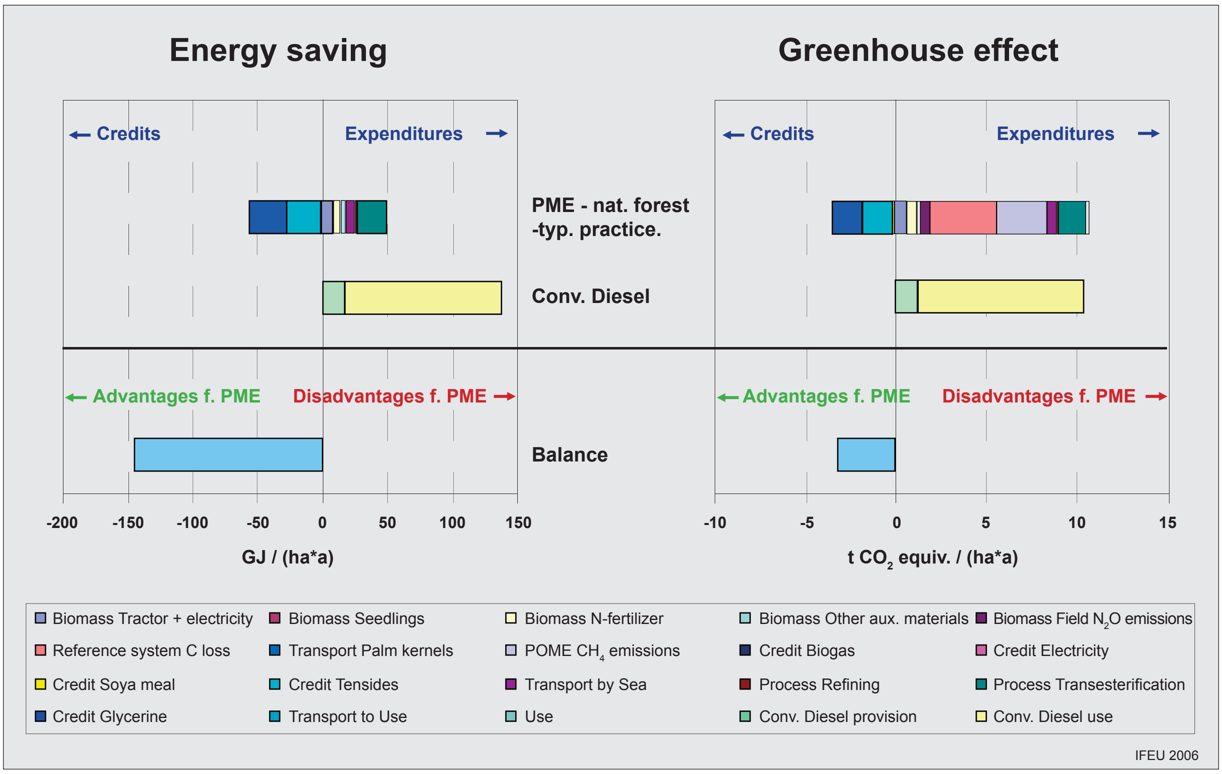
In the following section, the energy balances and greenhouse-gas balances of palm oil biodiesel (mobile use, see Fig. 6) and pure palm oil (stationary use, see Fig. 7) are calculated in the case that oil palms are cultivated instead of tropical natural forests. Since the carbon storage capacity of natural forest is higher than that of an oil palm plantation, the carbon loss has to be taken into account in the calculations as an environmental burden. According to (IPCC 1996), the natural tropical forest in Asia stores approx. 138 tonnes of carbon (C) per hectare, compared to only 30-50 tonnes C per hectare in a fully established oil palm plantation (IFEU 2006). On the basis of these figures we expect a C loss of 100 tonnes per hectare (this corresponds to a CO_2 loss of 365 tonnes per hectare) when a primary forest is converted into an oil palm plantation. In a life-cycle assessment, these 365 tonnes of CO_2 are debited to the oil palm plantation and, if appropriate, also to any subsequent use.

Mobile use

Fig. 9 shows the results of the energy balances and climate-gas balances of the life-cycle comparison between palm oil biodiesel and conventional diesel fuel shown in Fig. 6. It becomes clear that in some cases considerable amounts of fossil energy sources are used along the life cycle of PME from the production of the biomass via conversion up to its use as an energy source. On the other hand, considerable credits accrue particularly for palm-kernel oil (used as a tenside) and the resulting glycerine. The credits in the energy balance are actually bigger than the entire energy expenditure on the production of palm oil biodiesel. This is not the case with the climate-gas balances, since here a considerable amount of climate-affecting methane is given off during the storage of palm oil-mill effluent (POME); besides, significant quantities of carbon in the form of CO_2 are emitted into the atmosphere when natural forest is converted to plantations.

This last point represents the biggest uncertainty in the balances, whereas the other figures can be regarded as quite stable. For this reason, this point is discussed separately in section 4.2.5.

Fig. 9: Energy saving and greenhouse effect in the life-cycle comparison between palm oil biodiesel and conventional diesel.



Examples: energy expenditure on the production of palm oil biodiesel (PME) amounts to approx. 50 GJ; credits total approx. 60 GJ; annual overall saving of energy per hectare is approx. 150 GJ if palm oil biodiesel is used compared to conventional diesel.

When natural tropical forest is cleared for an oil palm plantation, there are unequivocal advantages for palm oil biodiesel in terms of fossil energy savings in the „overall balance of palm oil biodiesel versus conventional diesel fuel“. The same also applies in principle to greenhouse gases. However, it should be pointed out here that, in the results described here, the loss of carbon sustained in the conversion of primary forest into an oil palm plantation was written off over a period of 100 years. When shorter depreciation periods are used, the results can even dip into negative territory (see discussion in section 4.2.5).

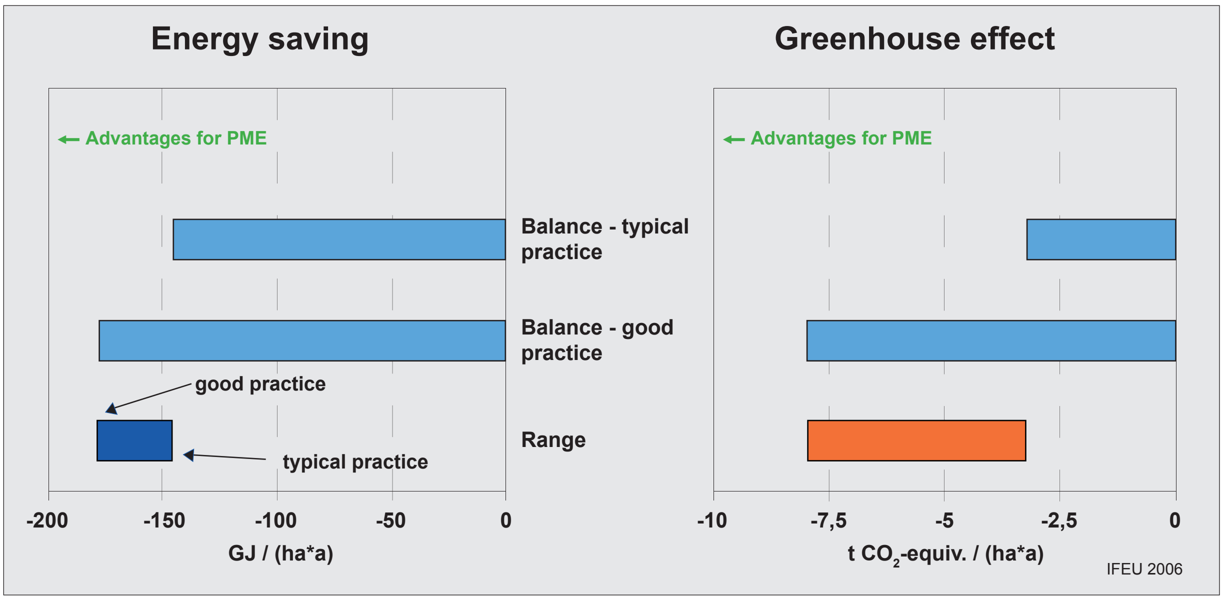
Scenarios

The results shown in Fig. 9 apply to average, globally typical methods of producing palm oil. By contrast there is optimization potential in some areas/are potential areas of improvement, e.g. better plantation management, better exploitation of by-products, exploitation of biogas in POME storage. In order to show the effects of different management methods on the results, a distinction is made between two management scenarios: „typical management“ and „good management“:

- „Typical management“: palm oil yield 3.5 tonnes per hectare per year. Only enough palm oil-mill residues (fibers and kernel shells) are combusted in the mill‘s own cogeneration unit to generate the power and steam needed to cover total process energy needs. The remainder is not used, it is returned to the plantations. The biogas emitted during effluent treatment (65% methane) escapes unused into the atmosphere.
- In the „good management“ scenario, surplus residues are used either directly on the spot or in a central biomass power station to generate electricity, earning electricity credits. Furthermore, the biogas from anaerobic POME treatment is collected and used for power generation. This energy is credited in the form of natural gas. Improved management increases the palm oil yield to 4.0 tonnes per hectare per year.

Natural-forest use leads to a climate-gas saving of 3 to 8 tonnes of CO_2 equivalents per hectare and an energy saving of approximately 150 GJ per hectare per year (see Fig. 10). It also becomes clear that „good management“ can achieve significant improvements: 2.5 times more greenhouse gases can be saved compared to customary palm oil production. Fossil energy savings can be increased by about 20%.

Fig. 10: Comparison of typical and good management. The lowest bar shows the margin of fluctuation of the results.



Stationary use

Fig. 11 shows the results for the four stationary uses of palm oil, each compared to conventional fuels. It becomes clear that the results of the energy balances and greenhouse-gas balances are analogous to those relating to the use of palm oil as palm oil biodiesel: Fossil energy sources and climate gases are definitely saved over the entire life-cycle comparisons.

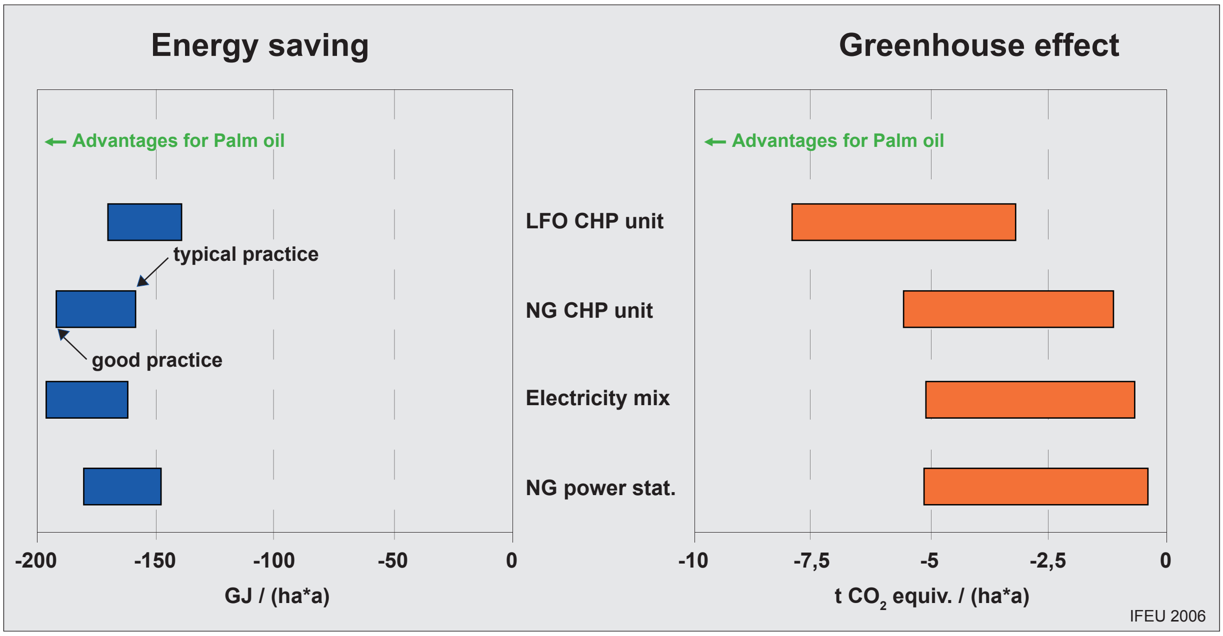
Stationary use is in the same category as mobile use with an energy saving of 140-195 GJ per hectare per year (total range/bandwidth?). This also applies to the results on greenhouse gases. The largest savings of climate gases are made with variant 1a (where palm oil replaces light fuel oil in a CHP UNIT). The main reason for this is that each source of conventional energy requires a different amount of energy to provide it, and emits a different amount of CO_2 per unit of energy content.

Here, too, it should be pointed out that in the results described here the carbon loss in the conversion of primary forest into an oil palm plantation affects the balance over a period of 100 years. If shorter depreciation periods were used, the results would be negative (see section 4.2.5).

Oil palm plantations

Note: The results shown in the graph and discussed here apply to the life-cycle comparison shown in Fig. 7, i.e. for the comparison between palm oil production and natural forest.

Fig. 11: Results for the complete life-cycle comparisons between pure palm oil used in stationary plants on the one hand and conventional power generation on the other for the four uses examined in the scenario „palm oil instead of natural forest“

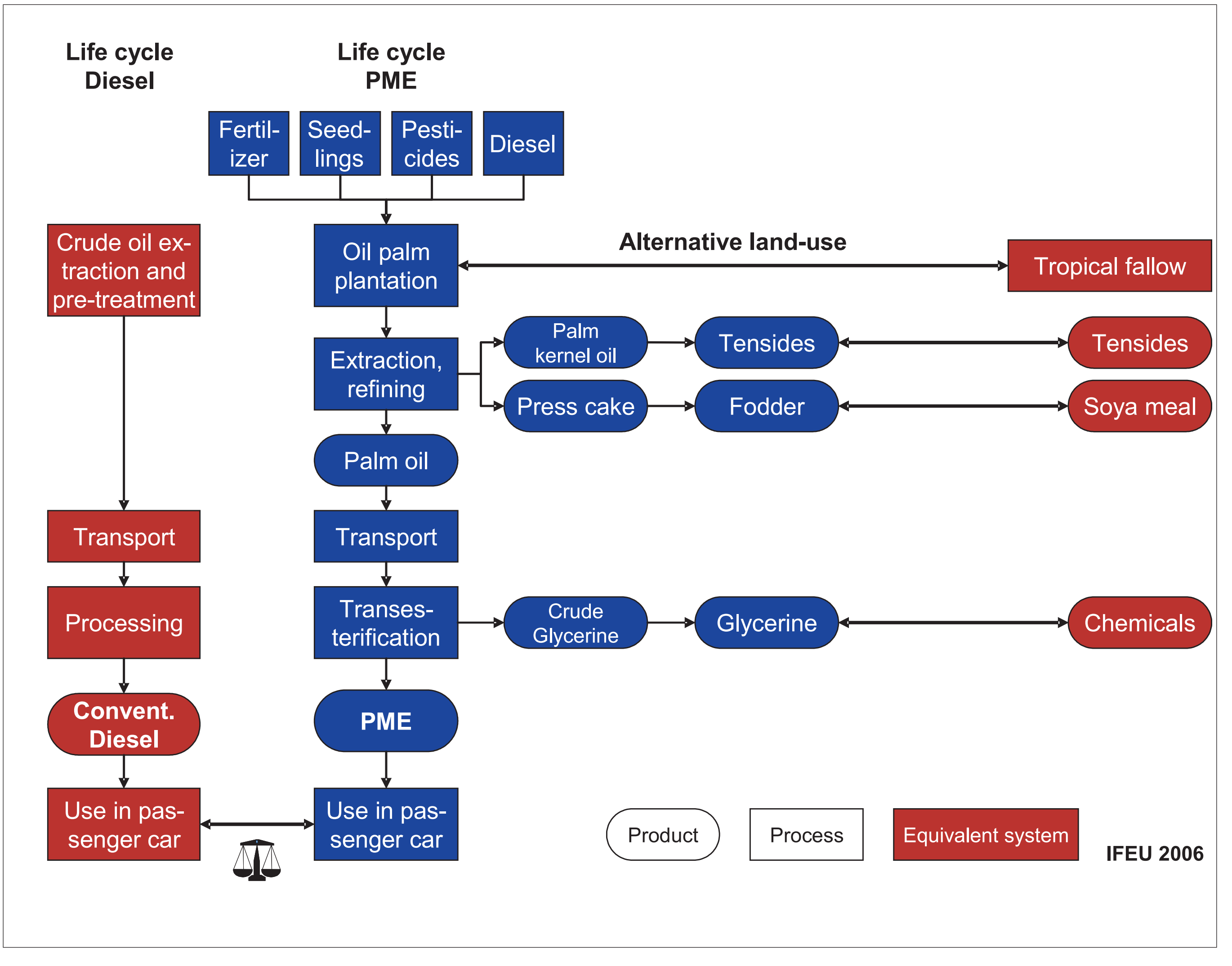


4.2.3. Oil palms on tropical fallow land

As already mentioned in section 4.1.3, fallow land in the tropics where natural tropical forests used to stand represents an enormous potential cultivation area for oil palms. 30-50 tonnes of carbon (C) per hectare are sequestrated by planting oil palms, and this is shown as credit on the balances (IFEU 2006). It is assumed here that a devastated area with negligible carbon content is planted with oil palms (otherwise it would presumably be used for agriculture).

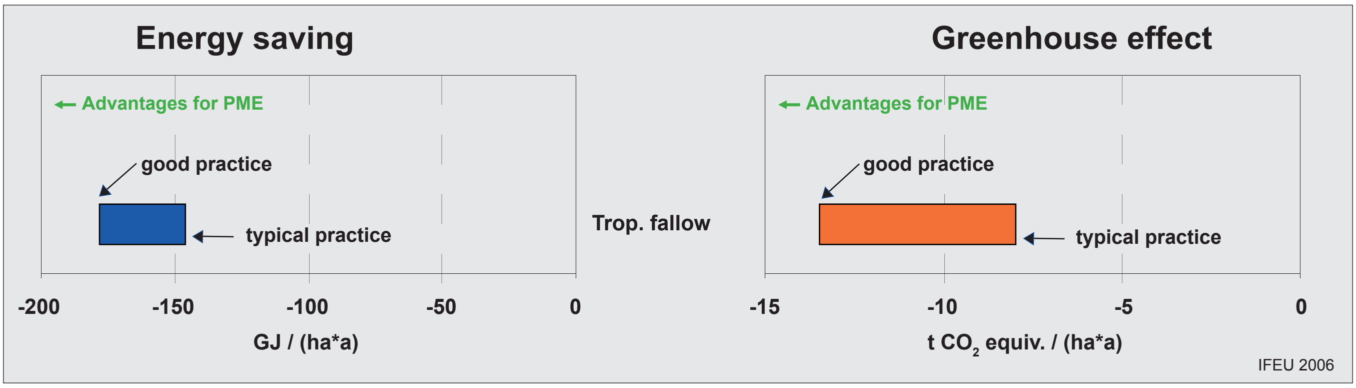
Fig. 12: Life-cycle comparison between conventional diesel and palm oil biodiesel (PME), both used in a diesel vehicle. Fig. 15/16 shows an example of a life-cycle comparison between conventional diesel and palm oil biodiesel (PME) with tropical fallow land as the alternative land-use.

Fig. 12: Life-cycle comparison between conventional diesel and palm oil biodiesel (PME), both used in a diesel vehicle.



When tropical fallow land is planted with oil palms, the energy-balance result is identical to the one with the natural forest option (see Fig. 10 and Fig. 11). In terms of greenhouse gases, by contrast, the result in the case of the fallow option (8–13.5 tonnes of CO_2 equivalents per hectare per annum) is much better, since additional carbon is sequestrated by the planting of the fallow land, and this is shown as credit on the balance. Despite the simplified assumptions on the carbon content of fallow land, the result can be regarded as qualitatively stable. However, the financial expense of establishing the plantation on such fallow land is several times higher than in the case of former natural forest land. Without corresponding incentives, therefore, it can be assumed that natural forest will continue to be cleared if rising demand leads to higher palm oil production in the future.

Fig. 13: Result of the life-cycle comparison between palm oil biodiesel (PME) and diesel fuel when tropical fallow land is planted.



4.2.4 Oil palms instead of other plantations

In addition to clearing natural forest and planting tropical fallow land, sometimes plantations of other crops (rubber, coconut, etc.) are converted into oil palm plantations. However, this means that products traded on the world market such as natural rubber or coconut oil will no longer be produced on this land and therefore have to be substituted by alternative products such as synthetic rubber. According to the basic rules of life-cycle assessments, this is taken into account by taking the equivalent benefit of the corresponding conventional products into consideration in the balance. In this case, therefore, the lost benefit is set off against/debited to the palm oil. Fig. 14 lists the options examined here and the corresponding credits. In addition to natural forest and fallow land (see above), the following three alternative types of land-use are examined as alternatives to oil palm plantations:

- Coconut: a coconut plantation is a possible alternative to an oil palm plantation. The coconut oil, which is used to produce tenside, is replaced by a synthetic tenside based on mineral oil. Coconut press cake, which is generally used as animal fodder, is substituted by soya meal.
- Rubber: a rubber plantation is a possible alternative to an oil palm plantation. Natural rubber is substituted by synthetic rubber (SBR) based on mineral oil.
- Cooking oil: palm oil from an existing oil palm plantation can be used as a bioenergy source instead of as a foodstuff. In this case the shortfall of cooking oil has to be substituted by a different cooking oil such as oilseed rape or sunflower oil. This requires additional land.

Fig. 14: Life-cycle comparison between conventional diesel and palm oil biodiesel (PME), both used in a diesel vehicle.

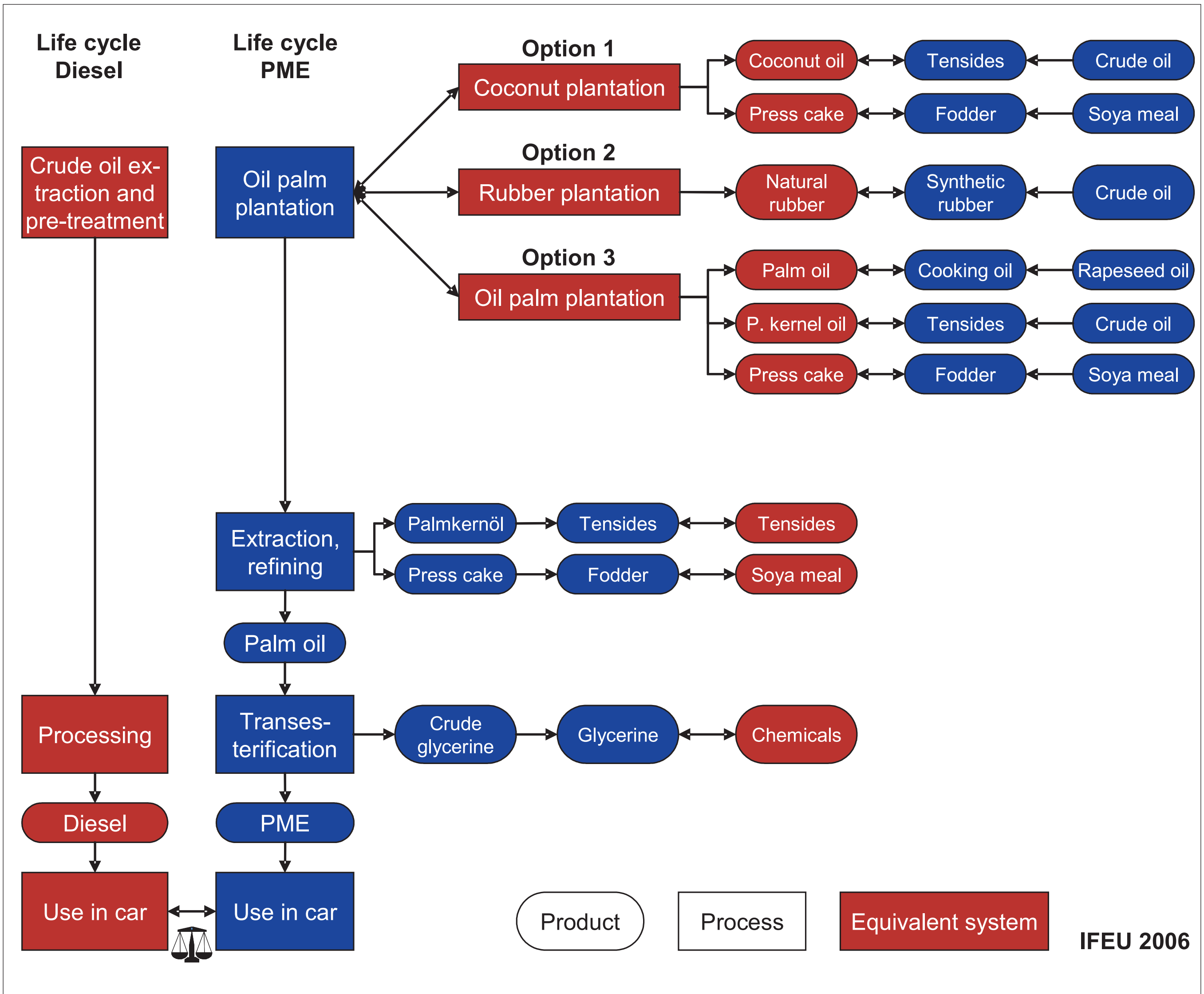
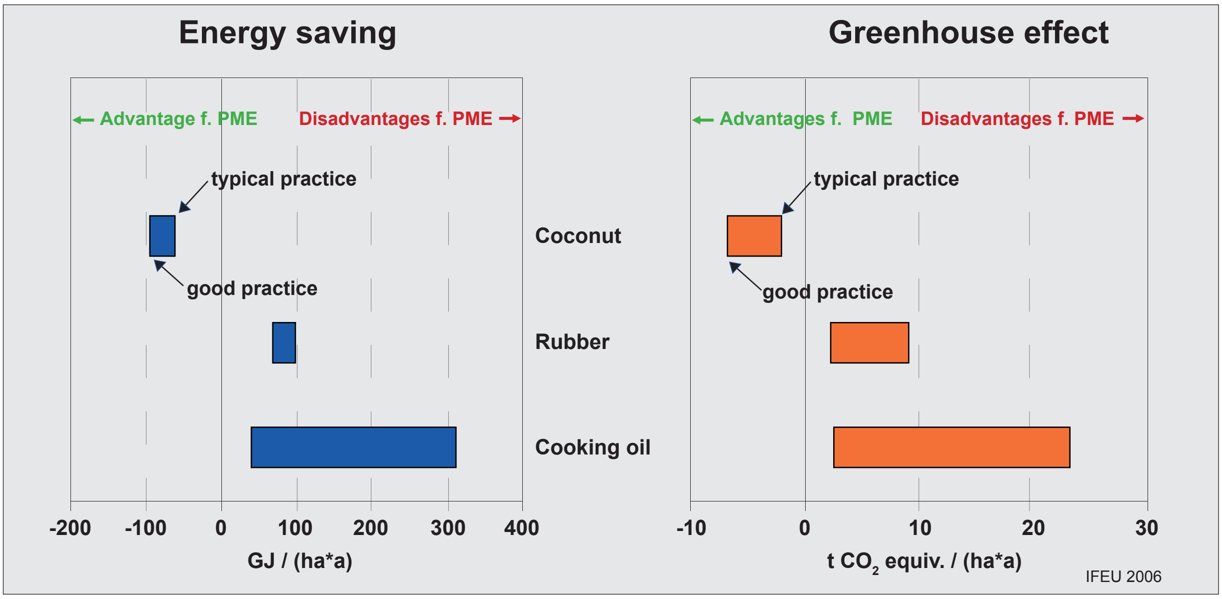


Fig. 15 shows the results for these scenarios: if oil palms are grown instead of other plantation crops, the results are much worse than in the conversion of natural forest; in the case of rubber and cooking oil, the positive result for palm oil actually becomes negative. This means that palm oil used to generate energy, when produced instead of rubber, leads to a higher net consumption of fossil energy and higher emissions of climate gases – despite the substitution of diesel fuel by palm oil biodiesel. Among other things, this is because the production of synthetic rubber requires a lot more energy than the production of diesel fuel.

The results on the stationary use of palm oil compared to the other possible land-uses, as discussed in Fig. 10, are analogous to the palm oil biodiesel results (see Fig. 11), which is why they are not discussed in detail here.

Fig. 15: Results of the life-cycle comparison between palm oil biodiesel (PME) and diesel fuel for the three examined alternative land-uses



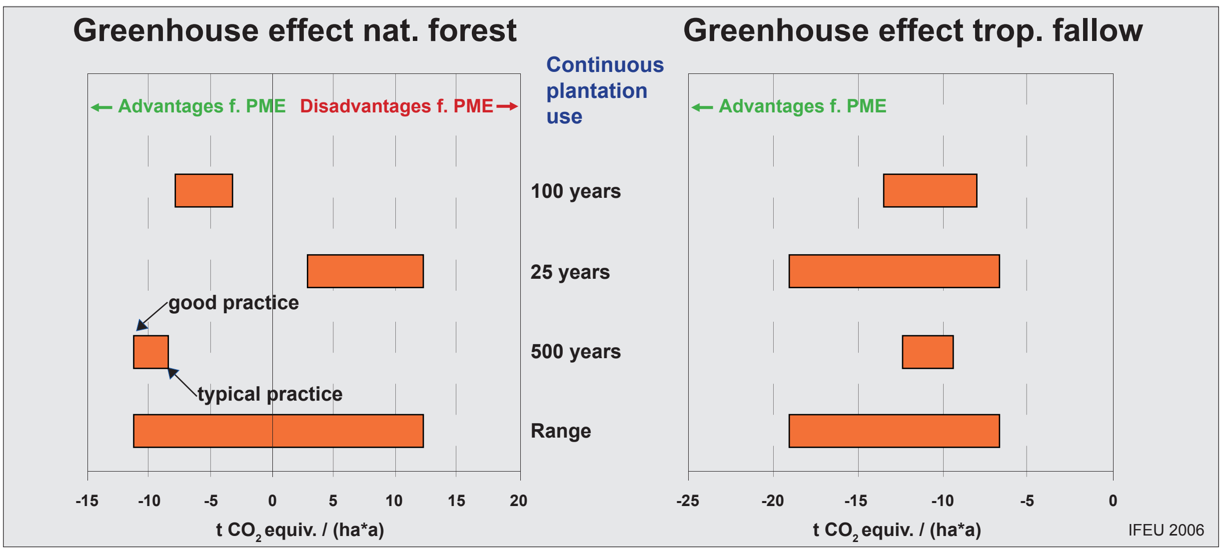
4.2.5 Land-use aspects

Charge/credit period

In the results presented up to now, the depreciation proposed by the IPCC is fixed at 100 years and continuous subsequent plantation use is assumed for the period thereafter. For natural forest the result of this approach is a climate-gas saving (see Fig. 10) of about 3-8 tonnes of CO_2 equivalents per hectare per year for the range "typical and good management". For fallow land it is between 8 and 13.5 tonnes of CO_2 equivalents per hectare per year (see Fig. 13).

If a period of only 25 years is fixed (approximately corresponding to one production cycle of an oil palm plantation), the overall balance for natural forest reverses its sign, i.e. over the entire plantation period of 25 years there would be an additional net climate-gas burden of about 12 tonnes of CO_2 equivalents year after year in the case of typical management, when palm oil biodiesel is produced on a plantation replacing natural forest. If fallow land is planted, a shorter set-off? period leads to an improvement in the balance: 7-19 tonnes of CO_2 equivalents per hectare per year could be saved (see Fig. 16).

Fig. 16: Effects of different depreciation periods of (100, 25 or 500 years) on greenhouse-gas savings for the natural-forest/fallow options assuming continuous use.



If the depreciation period is extended to 500 years (20 plantation periods), the annual greenhouse-gas savings for natural forest rise to approx. 8–11 tonnes of CO_2 equivalents per hectare; for fallow land, by contrast, the value is reduced to approximately 9-12 tonnes of CO_2 equivalents per hectare per year (see Fig. 16).

Subsequent use

Apart from the length of the set-off? period, the type of subsequent use also plays a decisive role. The following three scenarios are conceivable:

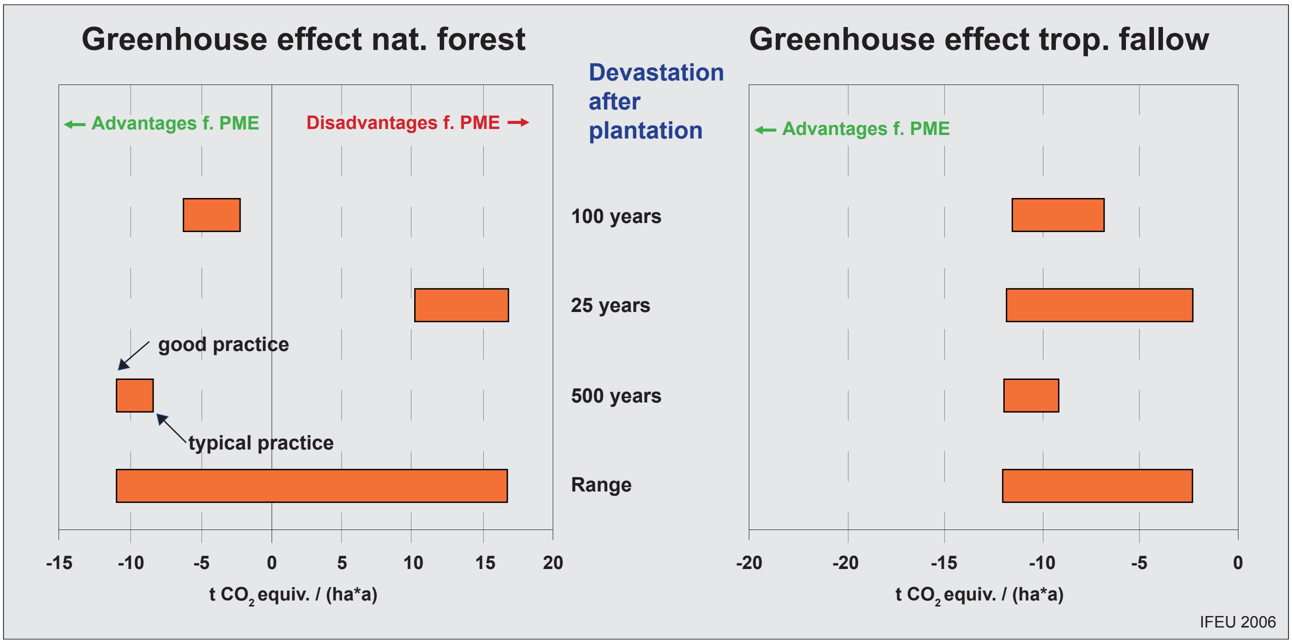
- Continuous plantation use (see above). The plantation is managed permanently and sustainably.
- One-off or repeated plantation use followed by the devastation of the land, since the plantation was not sustainably managed.
- One-off or repeated plantation use followed by development into secondary forest.

A sustainable, long-term management of oil palm plantations is doubtless possible. In the countries of south-east Asia in particular, we are assuming that, once land has been cleared, it will be used for a long time, due to pressure from the high population density. For this reason, we have based our fundamental scenarios on a set-off? period of 100 years, but also considered periods of 25 and 500 years. However, the sad experience of other tropical countries shows that devastation of the plantation land following a short- to medium-term exploitation phase is a quite realistic scenario. Fig. 17 shows that the results then worsen markedly compared to continuous, long-term use (see Fig. 16).

We regard development into a secondary forest after one-off use as improbable as an average option, which is why we have not given any results for it.

To sum up, it should be emphasized how sensitively the overall results depend on these two effects: i.e. on the actual size of the CO_2 loss or CO_2 sink, and on how to take this figure into account in the balance. This depends on how each plot of land will be used in the future, which no-one can predict in many cases.

Fig. 17: Effects of different depreciation periods (100, 25 and 500 years) on greenhouse-gas savings for the natural-forest and fallow options assuming that the land is degraded after 100, 25 or 500 years



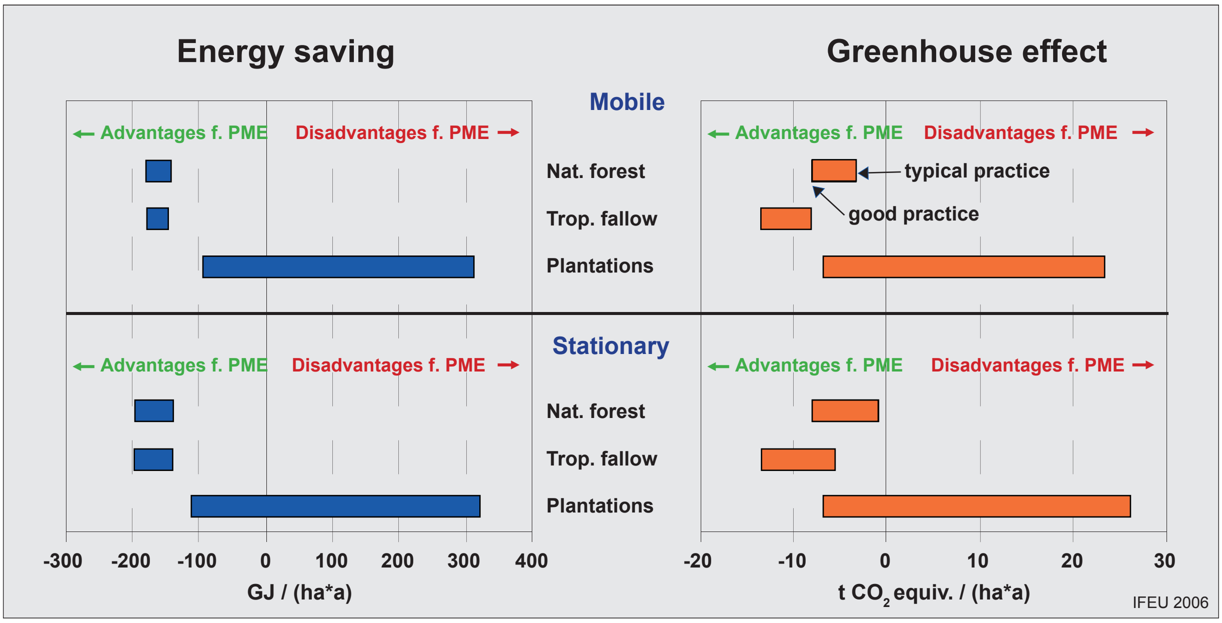
4.2.6 Overview of results for all alternative land-uses

Fig. 18 shows the results initially for both the mobile and stationary use of palm oil: over the entire life-cycle comparison in each case, i.e. compared to the respective conventional energy source and distinguishing between whether the palm oil plantations are cultivated instead of the natural forest, tropical fallow land or other crop plantations (cf. corresponding scenarios in sections 4.2.2. to 4.2.4.)

The main results are as follows:

- If oil palms are grown on tropical fallow ground or instead of natural tropical forest, then 150 GJ of fossil energy per hectare per year are unequivocally saved – comparing the complete life-cycles entitled „use of palm oil as a source of energy compared to conventional power generation".
- The results on greenhouse gases for the two specified options „natural forest" and „tropical fallow land" are analogous – i.e. advantages for the use of palm oil as an energy source – albeit with two differences compared to the energy balances:
  First: the results are more favourable when oil palm plantations are established on tropical fallow land than on former natural forest land, since carbon is sequestrated instead of being released.
  Second: The results shown in Fig. 18 were based on a depreciation period of the sequestrated or released carbon of 100 years. This depreciation period has only a slight influence in the „tropical fallow land" scenario compared to the „natural forest" option. While CO_2 savings are made under all the depreciation possibilities in the „tropical fallow" option, this is not the case with the natural forest: here, the shorter the depreciation period, the worse the result: in the case of set-off? periods of up to 25 years, i.e. only one plantation period, emissions actually increase (see section 4.2.5).
- It can therefore be concluded that planting oil palms on tropical fallow land is clearly more effective than clearing natural forest in terms of CO_2 savings.
- If, by contrast, oil palm plantations replace other plantations (rubber, coconut or cooking oil) then the results (here, too, over the entire life-cycle comparisons) are not uniform: advantages or disadvantages can result. Even when palm oil, a renewable energy source, replaces fossil energy sources, there can be a net increase in fossil-energy consumption and climate-gas emissions. This has to do with the fact that the energy balance and climate-gas balance of natural rubber, for example, are better that when oil palm is grown on the same land, even if the palm oil is used as an energy source.
- The result of the comparison between the stationary and mobile use of palm oil is that there are hardly any significant differences in the energy balances and greenhouse-gas balances.
- There is considerable optimization potential in the field of palm oil production and processing. Significant energy savings and even greater climate-gas savings compared to current, „typical" global palm oil production methods can be achieved if „good practices" are used in production in the future. The greatest potential for savings can be achieved by collecting the biogas from the effluent of the palm oil mills produced during anaerobic fermentation and using it as an energy source, by using all the fibers and kernel shells and by optimizing plantation management (also leading to higher yields). These opportunities for optimization are independent of whether the palm oil is used as an energy source or in the foodstuff industry. The balances described for the use of palm oil as a source of energy show the considerable potential for savings over the complete life cycles: over 15% energy saving and over 60% climate-gas saving.

Fig. 18: Results of the complete life-cycle comparisons between palm oil used as an energy source and conventional energy provision for mobile (palm oil biodiesel, PME) and stationary use (pure palm oil) differentiated according to the alternative land-use to the oil palm plantation



The range of the natural forest scenario differentiates between globally typical management and good management practices of palm oil production and processing

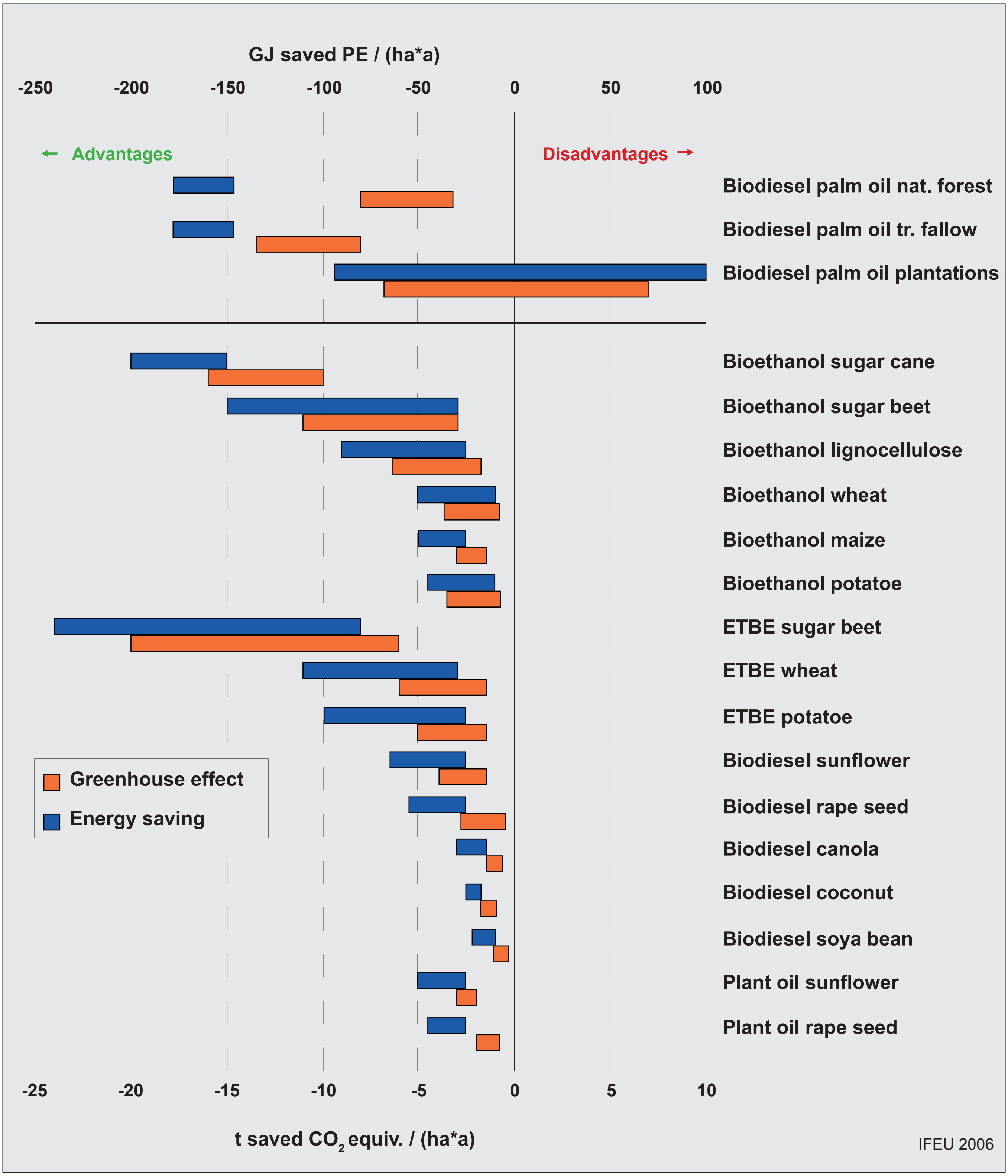
4.2.7 Comparison of palm oil biodiesel with other biofuels

Here are the results (see Fig. 19) of the life-cycle comparison between palm oil biodiesel and other biofuels made from grown biomass – in particular bioethanol (EtOH) as a petrol replacement, ETBE (ethyl tertiary butyl ether) as an antiknock agent, various biodiesels and pure rapeseed oil:

- When the oil palm is grown instead of natural forest or tropical fallow land, palm oil biodiesel, ethanol made from sugar cane, and ETBE from sugar beet have by far the best energy balances, i.e. the biggest fossil energy savings can be made per hectare with these biofuels.
- The results for palm oil biodiesel are not so unequivocal when it comes to saving climate gases: only oil palms grown on tropical fallow ground shows results that are about as high as with ethanol from sugar cane or ETBE from sugar beet and therefore more favourable than most of the biofuels mentioned.

  As regards the typical present-day way of producing palm oil instead of natural tropical forest, the climate-gas saving is no higher than with fuels made from sugar beet grown in temperate regions and less favourable than sugar cane grown in subtropical regions. And this is only the case if palm oil is grown instead of natural forest and the carbon loss when primary forest is transformed is written off over 100 years (see detailed discussion in section 4.2.5).
- There are already a number of alternatives to palm oil, at least when it comes to saving climate gases, which achieve the same benefits, but do not necessarily require natural tropical forest land.
- The results worsen markedly when palm oil is grown instead of other plantations: Here, the result shown in Fig. 18 initially remains valid: i.e. that palm oil biodiesel can even exhibit negative balances over the entire life-cycle comparisons, i.e. cause increased energy consumption and additional climate-gas emissions. Compared to the other biofuels, it also transpires that climate-gas savings under typical management regimes – even in the most favourable case for palm oil of planting coconuts as the alternative – are achieved or exceeded by many other biofuels.
- Here, too, we see very worthwhile optimization potential in the field of palm oil production and processing (see Fig. 10).

Fig. 19: Results of the energy balances and greenhouse-gas balances of different biofuels compared to their fossil-fuel counterparts in terms of annual savings of primary energy (measured in GJ) and climate gases (in tonnes of CO_2 equivalents) per hectare of grown biomass



4.3 Other environmental effects of palm oil production

Apart from the ecological spheres of influence already mentioned – energy consumption, greenhouse effect and land use – there are a number of other ecologically relevant areas that are linked to the production of palm oil. These are outlined briefly here without quoting individual figures, since there are not enough data for this.

Picture 3: Typical appearance of an oil mill for processing oil palm fruit. Photograph: IFEU

Emissions into the atmosphere

Some residues remain after the palm oil fruits have been processed to oil in the mill. These include empty fruit bunches (EFBs, approx. 22% of the weight), fibers (14%), kernel shells (7%) and effluent. Some of these residues, primarily fibers and kernel shells, are burned in the mill to generate energy. This leads to the emission of the pollutants typical of combustion – primarily nitric oxides, hydrocarbons and particles. Since no particularly sophisticated flue gas cleaning systems are installed as a rule, there are considerable pollutant emissions into the atmosphere which continue over the whole year as a result of daily operations.

Some oil mills also burn the empty fruit bunches in furnaces on the mill site and spread the ash as fertilizers on the surrounding plantations, since it is too cost-intensive and/or too much work to return them to then plantations and spread them. This burning is particularly harmful to the environment, because the fruit bunches are still relatively wet after the sterilization process, so that the combustion process can only be very incomplete – which is always the case when damp material is burned; this generates particularly high concentrations of pollutants. Here, too, no special flue-gas purification plants are installed. Although this method of „disposing“ of the fruit bunches is now banned in new factories in countries like Malaysia, it is still widespread worldwide. Even in Malaysia an estimated 10% of all plants are still affected.

Emissions into the hydrosphere

The effluent from the palm oil mills is subjected to anaerobic treatment on the mill site. In factories that try (at least to some extent) to achieve a sustainable system of palm oil production, this is predominantly done in open ponds; biogas – consisting predominantly of the climate-relevant gas methane – escapes into the atmosphere in this process (see section 4.2.2). Today, some of the anaerobically treated effluent is distributed in the surrounding plantations by ditch duct systems; often, however, it simply flows into a runoff ditch, since use on the land involves high costs. As a result, significant quantities of nutrients are still discharged into the rivers and pollute the ecosystems there, despite treatment. Only the mud which is occasionally drawn off from the ponds is used as a fertilizer on the plantations.

Furthermore, not all plants in the world have an appropriate concept for treating oil-mill effluent. In places where the effluent is untreated or insufficiently treated before it flows into the rivers, the risk to the aquatic ecological system is particularly high.

Picture 4: Effluent arising from the extraction of palm oil is temporarily stored in a cooling basin. Photograph: IFEU

Picture 5: Residue from palm oil extraction, partly used for power generation. Photograph: IFEU

Land use
During the refining of the raw palm oil and palm-kernel oil, approx. 9 kg of spent Fuller‘s earth accumulates per tonne of oil; at the moment this waste is dumped. Over 120,000 tonnes had to be disposed of in Malaysia alone in 2003. This required a corresponding amount of dumping ground, i.e. land otherwise available to nature.

4.4 Ecological optimization potential

As already mentioned in the previous sections, a number of residues are produced during palm oil extraction which, at present, are only insufficiently used or even have to be disposed of to the detriment of the environment. The main ones are the fibers, kernel shells and empty fruit bunches. There is significant potential for effective optimization here.

At present, about half of the fibers and kernel shells are burned inside the mill for power generation; as a result, the entire mill process can be operated with an autonomous power supply. The other half is normally used to stabilize the roads and tracks in the plantations – for lack of any other use, since returning the material as fertilizers is inefficient. Similarly, combustion for power generation is often not possible, since surplus electricity cannot be exported because most plantations are not connected to the electricity grid (Ma et al. 1994).

In the future, therefore, every effort should be made to use the remaining fibers and kernel shells everywhere and completely as an energy source, for example by connecting the palm oil mill to an electricity grid or by selling the raw material and using it as a source of energy elsewhere, as is already practised in isolated cases in Malaysia.

The large quantities of empty fruit bunches that accumulate cause the oil mills major logistical problems. Some of the oil mills take them back to the plantations in the empty trucks and – ideally – distribute them as mulch between the rows of palms. Since this work is extremely laborious and it is almost impossible to distribute the material evenly, in some cases it is simply dumped; at best it is spread around haphazardly, so that its soil-improving and fertilizing effect is not optimally exploited. Furthermore, in some cases the empty fruit bunches are still burned today in furnaces on the mill premises, and only the ashes are spread as fertilizer in the surrounding plantations.

There are several further possibilities for optimization. On the one hand, using suitable technologies the fruit bunches can be not only burned but also used to generate power. This also makes more economic sense than mulching (N et al. 2003). Since the oil mills are already power-autonomous by burning the shells and fibers, the oil mills would have to be connected to electricity mains for this purpose. Another alternative would be to use the fruit bunches internally for energy provison associated with selling all the fibers and kernel shells. Or else the fruit bunches could be burned together with the surplus of fibers and kernel shells in a central biomass power station (Ma et al. 1994). To achieve this, however, the bulky fruit bunches would have to be chopped up or pelleted and their high humidity content (65%) reduced.

There are also efforts to use the fruit bunches to make materials. Since they contain 30% cellulose they could replace approx. 30% of rubber-tree wood, a raw material (which is becoming increasingly scarce) used in the production of MDF (medium-density fiberboard) (Ridzuan et al. 2002 and Ropandi et al. 2005). Cellulose for paper manufacture or compost substrate (see below) can also be made from the empty fruit bunches.

In short, there are a number of options for using the fruit bunches efficiently. On the one hand this would avoid the environmental impacts otherwise caused; on the other there would actually be environmental advantages such as savings energy and climate gases, so that all efforts should be made to fully tap this potential in the future.

Sections 4.2.2 and 4.3 described the effects of the biogas missions from the palm oil mills' effluent on the energy balances and overall climate-gas emissions, as well as its other ecological effects.

The currently practised anaerobic treatment of the effluent is predominantly carried out in open ponds. About 60-70 m³ of biogas containing 65% climate-relevant methane escapes into the atmosphere for every tonne of palm oil produced during this process. Thus there is considerable improvement potential here: the methane contained in the biogas should be collected in closed biogas plants and used for power generation. On the one hand, this would prevent the escape of methane (a virulently climate-affecting gas, whose affect on the climate is about 23 times that of CO_2) and save additional fossil energy, thus preventing the release of fossil CO_2 when fossil energy sources are used. An additional side effect would be that this would somewhat reduce the amount of space required by palm oil mills, since the conventional pond systems would no longer be needed. Using established technologies, the substrate that remains after the biogas has been extracted can be spread over the surrounding plantations and have its fertilizing effect there.

In order to make optimum use of the nutrients in the oil mills' effluent, the German Federal Research Institute for Agriculture in Braunschweig has proposed a system for composting the anaerobically pre-treated effluent together with chopped up fruit bunches. This would bring all the nutrients together in a single product which could be used as an organic fertilizer in the plantations (Schuchardt et al. 2005).

Section 4.3 described in detail the (in some cases extremely serious) pollution of the atmosphere with nitric oxides, hydrocarbons and particles by the combustion of fibers, shells and fruit bunches.

The plants currently used for burning the fibers and shells or empty fruit bunches should be re-equipped with state-of-the-art pollutant-filtering systems (dust cyclone, flue-gas scrubbing, etc.), and else new installations should only be approved if they have this technology.

Another focus is the plantation industry itself, whose global practices not universally based on good technical management, a fact that is reflected by marked differences in yields per hectare (see section 2.2).

There are more areas in which the plantation industry could improve its level of efficiency, although this subject can only be touched on here for the sake of completeness. Certainly the most important priority here is the need for fertilizer to be spread in a needs-oriented manner using state-of-the-art techniques, possibly using the residues from the palm oil mills. As a rule this would reduce negative environmental impacts and raise yields at the same time. Furthermore, owls can be used to combat rodents, especially rats, instead of spreading rodenticides; this is already practised on some plantations. Another important issue is species diversity/biodiversity, which is reduced to a minimum on oil palm plantations that are run as monocultures. Here, too, there is a lot of potential for efficiency improvements.

Picture 6: Fruit bunches after removal of the individual fruits, partially used as mulch in the plantations. Photograph: IFEU

Picture 7: Fresh fruit bunches made up of large numbers of individual fruits. Photograph: IFEU

There are also further optimization opportunities, such as a process for recycling the Fuller's earth used in palm oil refining (see section 4.3). This consists of two steps: first the oil is extracted from the spent Fuller's earth by solvent extraction; then the Fuller's earth is processed by a thermal treatment (Cheah & Siew 2004). These optimization possibilities will not be examined in greater detail here, however.

4.5 Future land requirements for palm oil cultivation

The best way to gain an overview of the world market for biodiesel – and to calculate from this the amount of land that will be needed for palm oil cultivation until the second generation of biofuels can take over in around 2020 or 2030 – would be to predict the development of the crude-oil price and the biofuel policies of the EU and other major consumer countries. However, the EU has only fixed its objectives until 2010, and it is impossible to do much more than guess how the price of crude oil is likely to develop.

As far as the EU is concerned, the „Directive of 8 May 2003 on the promotion of the use of biofuels or other renewable fuels for transport" (CEC 2003a) calls on the member states to ensure that biofuels reach a specific minimum share of their markets. The reference value is 5.75% for 2010 and relates to the total energy content of all fuels. This means that member states are free to choose the exact percentage of diesel and gasoline they want to substitute. They are also free to choose which biofuel(s) to use to reach this objective. For reasons of availability, however, the choice is largely limited to first-generation biofuels, i.e. biodiesel, bioethanol and bio-ETBE made from various raw materials, since only negligible quantities of second-generation biofuels will be available before 2010.

In principle, pure palm oil and palm oil biodiesel (PME) can also be used to reach these targets. As shown in chapter 2.3.1, palm oil biodiesel cannot meet the currently valid standards at present, either in its pure form or as a blended fuel. However, if the planned amendment of the DIN EN 590 diesel fuel standard were to be adopted, so that PME's low-temperature properties no longer stood in the way of the production of palm oil biodiesel, the result could be a huge potential market.

This raises the question of what effect the establishment of palm oil biodiesel in the European market would have. The analysis focuses here on whether there is enough palm oil available on the world market, whether production would have to be expanded in future – and if so, where.

The FAO expects production of palm oil to increase from 25.6 million tonnes of oil equivalent in 1999/2001 to 54.2 million tonnes in 2030. Because the demand for bioenergy is still growing, the FAO considers an annual increase in the technical-industrial field of 3.2% to be likely, compared to an annual growth of only 1.5% in the food sector. In view of this, the FAO, too, regards this as a potential threat to forests in the producer regions (FAO 2006b).

For the main producer countries in southeast Asia, extrapolations based on high annual growth rates of 5 to 12% – and assuming the continuation of present cultivation systems – expect the amount of land required in Malaysia to increase from 3.5 to 5.1 million hectares by 2020; in Indonesia the figure would jump from currently 5 to 16.5 million ha. If better management techniques are introduced (efficient land-use, ban on converting natural forest, better cultivation methods), the predictions are 4.3 million ha for Malaysia and 9.0 million ha for Indonesia. Hence, even if efficient management techniques are used, at least 3 or 4 million hectares of more land would be needed to grow oil palms in Indonesia.

Government agencies expect the need for additional land for palm oil cultivation to be as high as 30 million ha; provincial governments in Indonesia expect to issue licenses for 20-22 million ha in the wake of decentralization. However, rough estimates put the amount of available fallow land at no more than 10 million ha (Dros 2003). By as early as 2010, Indonesia intends to make 3 million ha of land available for palm oil production and to build 11 refineries (cf. chapter 3.6.). Since establishing new plantations in cleared natural forest areas is economically more profitable than converting fallow land, the interests of the timber and plantation industry come into play here. Because of the political realities in the main producer countries of Malaysia and above all Indonesia, it must be expected that, despite all commitments to international agreements such as the Convention on Biological Diversity (CBD), tropical rainforest will be cleared for oil palm cultivation unless effective regulatory mechanisms have a real impact.

Furthermore, of all the possible options (clearing the natural forest, use of fallow land, rededication of other plantations), the use of fallow land promises the biggest potential savings of fossil energy and greenhouse gases. Because of the uncertainties surrounding the longer-term prospects for subsidies and compulsory blending schemes in the EU after 2010, estimates for Europe can only be given up to 2010. According to the European Biodiesel Board, only 1.4% of total fuel consumption is covered by biofuels, despite a target market share of 2.0% that was already envisaged for 2005; biodiesel accounts for 80%, ethanol (gasoline substitute) for 20%. In turn, 90% of biodiesel is made from European rapeseed, with production of rapeseed biodiesel (RME) totaling 3 million tonnes in 2005. Biodiesel has a market share of 1.5% of total diesel consumption (EBB 2006a, EBB 2006b and UFOP 2006).

If Germany put the appropriate subsidies in place, it could meet the target of a 5.75% share of total fuel, since it has enough agricultural land available to produce the necessary biomass and rapeseed itself. By contrast, the EU as a whole lacks the raw materials in this field. This gap could be filled in the medium or long term with ethanol fuel produced in Europe; however, the technology is not in place (UFOP 2006).

According to the oil-plant growing and processing associations (UFOP and FEDIOL), imports of palm oil are a possible alternative with a potential biodiesel market share of up to 20% by 2010, compared to about 10% in 2005 (UFOP 2006, Krishna & Mudeva 2006). By 2010, assuming a 5.75% biofuel share by this time, (FEDIOL 2006) expects that EU-wide biodiesel consumption will average 12 million tonnes, and that this will be made up of at least 5.8 million tonnes of European rapeseed oil and up to 2.5 million tonnes of imported palm oil – i.e. 20% of biodiesel consumption. Soybean oil (approx. 2.4 million tonnes) and other vegetable and animal oils are further raw-material sources for biodiesel. Assuming an average yield of 3.25 tonnes per hectare per year for Indonesian palm oil (Dros 2003), this means a land requirement of approx. 770,000 ha for the European biodiesel market – in a producer country that is already particularly hard hit by natural-forest clearing. In addition to this, there is an unknown level of demand for stationary use.

The future level of consumption (or demand for imports) of palm oil forecasted by energy crops associations is shown above, and the amount of land required has been calculated on that basis. By contrast, the calculations of the IFEU Institute in Table 9 provide an overview of how much land would be required in order for palm oil biodiesel to substitute 1% of diesel fuel or 1% of total fuel respectively in the EU-25, Germany, Switzerland and the Netherlands on the basis of 2005 consumption levels. It transpires that the additional amount of land required is very significant – e.g. over 1 million ha to substitute 1% of the EU-25's fuel with palm oil biodiesel. Every percentage of substituted diesel fuel in Germany corresponds to 1% of the current worldwide production of palm oil on 8.6 million ha of land. Every substituted percentage of diesel fuel in the EU-25 corresponds to as much as 8%. The figures for every percentage of total fuel substituted are 2% and 12% respectively. Furthermore, countries like Malaysia and Thailand have also formulated political targets for using biofuel – in this case specifically palm oil (see chapter 3.6).

Tab. 8: Amount of land (in hectares) required to substitute 1% of the respective fuel consumption

	Hectarage required to substitute 1% of	
	diesel fuel	total fuel consumption
Germany[1]	102,000	189,000
Switzerland[2]	6,000	18,000
Netherlands[3]	19,000	34,000
EU-25	711,000	1,035,000

IFEU 2006 based on [1]MWV 2005;
[2]Erdöl-Vereinigung 2005;
[3]VNPI 2006

Compared to the substitution of fuel by palm oil, the results for substituting electricity are even more pronounced (see Table 12): the amount of oil palm plantation land needed to cover 1% of Europe's electricity needs is about twice the amount needed to substitute 1% of the fuel market, i.e. about 2 million ha.

Tab. 9: Amount of land (in hectares) required to substitute 1% of the respective electricity consumption

	Hectarage required to substitute 1% of electricity consumption
Germany	365,000
Switzerland	42,000
Netherlands	59,000
EU-25	1,927,000

IFEU 2006 based on European Commission 2003

5 Outlook

On the basis of the present study it is evident that the demand for and thereby the production of palm oil are experiencing strong growth. The FAO predicts that global demand will double between 2000 and 2030 (FAO 2006b). The use of palm oil as an energy source is leading to a significant increase in the demand for palm oil.

The results of the energy balances and greenhouse-gas balances on the stationary and mobile use of palm oil demonstrate that palm oil can save enormous quantities of fossil energy and greenhouse-gases in comparison to other vegetable oils, particularly when plantations are cultivated on deforested fallow land. The customary method of preparing additional areas for cultivation is not however to use fallow land, but particularly in Indonesia to lay out palm oil plantations on specially cleared natural forest areas. Increased pressure on the palm oil markets due to the rapid growth in demand for palm oil gives rise to speculation that further natural forest land is threatened with conversion into oil palm plantations, not only in Indonesia, but also in Sabah, Sarawak (Malaysia), in Papua New Guinea, in Colombia and Ecuador as well as in the longer term in Africa. The new establishment and operation of plantations is not only accompanied by a dramatic loss in the diversity of species, but in addition mostly also with major social problems, such as poor working conditions on the plantations and land rights conflicts with the resident population (Colchester et.al. 2006)

Environmental assessment and nature conservation

In addition to savings in fossil energy and emissions of climate gases, other effects on the environment and nature should also be taken into consideration in a comprehensive environmental assessment. These include the atmospheric and water pollution burdens connected with palm oil production as well as consequences for the diversity of species. Even where the energy balances and greenhouse-gas balances are positive, the protection of biodiversity as well as the unique natural habitats of plants and animals does not justify additional clear-cutting or use of tropical primary forests. This is because although there are a number of other options to save energy and protect the climate, a loss of species diversity caused by clear-cutting tropical forests is irreversible.

Energy balances and climate-gas balances can serve as a comparative basis for the suitability of different energy sources or also in order to identify exemption criteria for individual harmful or inefficient practices. And they can also serve more extensive environmental and nature conservation policy decisions, e.g. to call for optimization measures. However scientifically backed analyses are necessary for this. Not all aspects could be looked at in detail in this respect in the present study.

Thus for example, recently published studies showed that the (slash and burn) clearance of moor woodland released exorbitant amounts of CO_2 (Reijnders & Huijbregts 2006). As many of the tropical lowland forests which are suitable for the cultivation of oil palms are situated on swampy soils, the oil palm plantation’s favourable greenhouse-gas balance is put into perspective and, if the emissions produced by the degradation of peat are taken into consideration, could even result in it being negative. The depreciation periods for the release of carbon dioxide also have a considerable role to play with regard to the results of the study: As far as this is concerned, the study was able to show that the greenhouse-gas balance throughout the 25-year economic exploitation phase of an oil palm plantation, with a proportionate crediting of the carbon difference, is clearly negative. Concerning the scenario of the conversion of natural forests, the balance only turns to good account after very long exploitation periods. In this context therefore a discussion of subsequent uses of the land used is called for.

Thus three plots arise from the present energy balances and climate-gas balances: A need for research to specify particular sections of the balances has been identified, including the carbon balances of the moor soils, the carbon reserves above and below ground and the previous and subsequent uses of palm oil plantation areas. Secondly, clear recommendations for the future optimisation of palm oil production to reduce the climate-relevant gases have been derived, which are to optimise palm oil production in the existing plantations and during processing. Thirdly the consequence that the climate-gas balances of palm oil on fallow land should turn out positively needs to be verified from the viewpoint of practical suitability.

Certification of palm oil: possibilities and limitations

The WWF, along with companies from the palm oil sector, food companies, banks as well as representatives of civil society, have created the Roundtable on Sustainable Palm Oil (RSPO), an organisation meanwhile comprising more than 160 full members. Through the members of RSPO about 40% of global palm oil production is covered, and in addition the most important buyers and processors of palm oil are represented in the RSPO. Even outside the palm oil sector the RSPO is regarded as the major global player concerning sustainable palm oil production.

The background to and goal of the RSPO is the sustainable production of palm oil as well as its promotion and use. In a first step, with the participation of all players, the principles and criteria of the RSPO were developed and passed in 2005. These guidelines stipulate that both ecological and social minimum conditions have to be fulfilled.

The new establishment of oil palm plantations requires among other things an environmental impact assessment (EIA) as well as a social impact assessment (SIA). Furthermore the clearance of natural forests with high ecological or cultural significance (high conservation value – HCV) is prohibited. The separating out of the HCV takes place within a participative land-use plan, which can be a part of the EIA. The RSPO guidelines are supported by a number of environmental and development organisations including the WWF, Oxfam and Sawit Watch. They are to represent a minimum requirement both for the conventional use of palm oil as well as its use as an energy source. Certainly the RSPO guidelines do not include any requirements with regard to greenhouse-gas balances; however the prevention of greenhouse-gas emissions, such as methane emissions in sewage ponds, is given as a general goal.

The present study makes it clear that an optimisation of palm oil production would have a considerable influence on the emission of greenhouse-gases and that big potential savings can be made. Several of these optimisations are partially covered by the RSPO guidelines, as has been mentioned already. Others require a weighing up between the greenhouse-gas emissions target and the advantages of prior practice, in order to ensure that no undesirable side effects (e.g. “leakage“) occur, e.g. when empty fruit bunches are no longer used as fertilizer in plantations, but rather primarily for power generation, the result could be a greater need for mineral fertilizers.

Effects of using palm oil as a source of energy on its use as a foodstuff

Neither the energy and greenhouse-gas balances, nor the RSPO guidelines, take a further potential side effect of the use of palm oil as an energy source, the financial burden on households in developing countries who depend upon palm oil as a foodstuff, into consideration. The apparent growing demand for palm oil has already led to an increase in world market prices. These price rises and also the foreseeable competition between conventional use and use as a source of energy are ultimately passed on to the end consumers. This primarily affects consumers from developing countries with low incomes, who moreover are often not able to fall back on other products.

Optimization potential: first and foremost the use of fallow land

There are in principle two options available to supply the growing global demand for palm oil for conventional use and as a source of energy. On the one hand the average productivity of oil palms can be increased. There is great potential particularly in Indonesia in this respect (Dros 2005). The second option consists of the expansion of the existing areas under cultivation. For this purpose the remaining tropical lowland forests should be comprehensively excluded where possible. Rather than this land, previously cleared, unused fallow land such as the so-called alang-alang areas should primarily be converted into in oil palm plantations. Initial estimates indicate that there is potentially enough fallow land available to supply the greater part of future palm oil requirements. An evaluation of the fallow land available with regard to its ecological and social importance as well as its potential to serve as a production area for palm oil plantations certainly represents one of the most important prerequisites for the future use of this land as a palm oil production area.

Gaps in knowledge and research needs

The forecasts of various institutions make it clear that palm oil will have an important role to play in future both in foodstuff production as well as for bioenergy. Chapters 2 and 4.5. The development of new areas for the cultivation of palm oil thus represents an important task from an environmental and nature conservation point of view. Exploring the availability of fallow land for palm oil production and ascertaining the feasibility and economic viability of this land option, provides a future research need.

The sustainable use of palm oil as an energy source involves pressing ahead with the development and establishment of internationally valid sustainability standards for bioenergy in which, in addition to the greenhouse-gas balances, land-use changes are also documented. A European as well as internationally recognized sustainability standard for bioenergy should include and use existing voluntary systems such as the RSPO. The RSPO certification system needs to be reviewed to see to what extent further criteria are necessary, in view of the increasing importance of energy source use such as e.g. the preparation of greenhouse-gas balances. An investigation is required as to how greenhouse-gas balances can be feasibly and cost-effectively introduced and prepared for the use of palm oil as an energy source.

The example of palm oil production and use clearly shows that a debate on the international establishment of standards for the production and use of biomass - irrespective of whether palm oil is used as an energy source or as a foodstuff – makes sense. The product flows cannot be accordingly separated from use, so that also with regard to other potential sources of energy which are likewise processed as foodstuffs, a comprehensive approach to the development of sustainability standards would appear helpful.

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PEAT-CO2

Assessment of CO2 emissions from drained peatlands in SE Asia

Report R&D projects Q3943 / Q3684 / Q4142

2006

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WETLANDS INTERNATIONAL

ALTERRA WAGENINGEN UR

PEAT-CO2

Assessment of CO_2 emissions from drained peatlands in SE Asia

1st edition
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Summary

Forested tropical peatlands in SE Asia store at least 42,000 Megatonnes of soil carbon. This carbon is increasingly released to the atmosphere due to drainage and fires associated with plantation development and logging. Peatlands make up 12% of the SE Asian land area but account for 25% of current deforestation. Out of 27 million hectares of peatland, 12 million hectares (45%) are currently deforested and mostly drained. One important crop in drained peatlands is palm oil, which is increasingly used as a biofuel in Europe.

In the PEAT-CO2 project, present and future emissions from drained peatlands were quantified using the latest data on peat extent and depth, present and projected land use and water management practice, decomposition rates and fire emissions. It was found that current likely CO_2 emissions caused by decomposition of drained peatlands amounts to 632 Mt/y (between 355 and 874 Mt/y). This emission will increase in coming decades unless land management practices and peatland development plans are changed, and will continue well beyond the 21st century. In addition, over 1997-2006 an estimated average of 1400 Mt/y in CO2 emissions was caused by peatland fires that are also associated with drainage and degradation. The current total peatland CO_2 emission of 2000 Mt/y equals almost 8% of global emissions from fossil fuel burning. These emissions have been rapidly increasing since 1985 and will further increase unless action is taken. Over 90% of this emission originates from Indonesia, which puts the country in 3rd place (after the USA and China) in the global CO2 emission ranking.

It is concluded that deforested and drained peatlands in SE Asia are a globally significant source of CO_2 emissions and a major obstacle to meeting the aim of stabilizing greenhouse gas emissions, as expressed by the international community. It is therefore recommended that international action is taken to help SE Asian countries, especially Indonesia, to better conserve their peat resources through forest conservation and through water management improvements aiming to restore high water tables.

Contents

1 Introduction

1.1 Background

Peatlands cover 3% (some 4 million km^2) of the Earth's land area (Global Peatlands Initiative, 2002) and store a large fraction of the Worlds terrestrial carbon resources: up to 528,000 Megatonnes (Gorham 1991, Immirzi and Maltby 1992), equivalent to one-third of global soil carbon and to 70 times the current annual global emissions from fossil fuel burning (approximately 7,000 Mt/y in 2006 in carbon equivalents or 26,000 Mt/y in CO_2 equivalents).

This carbon store is now being released to the Earth's atmosphere through two mechanisms:

- Drainage of peatlands leads to aeration of the peat material and hence to oxidation (also called aerobic decomposition). This oxidation of peat material (which consists of some 10% plant remains and 90% water) results in CO_2 gas emissions. Much of the dry peat matter is carbon (50% to 60% in SE Asia, depending on peat type).
- Fires in degraded peatlands result in further CO_2 gas emissions; fires are extremely rare in non-degraded and non-drained peatlands.

Most rapid peatland degradation presently occurs in SE Asia where the peatlands are being deforested, drained and burnt for development of oil palm and timber plantations, agriculture and logging. Apart from CO_2 emissions, these developments are also a threat to the remaining biodiversity in SE Asia as the peatlands are an important habitat for many endangered species, including Orang Utan in Borneo and Sumatran Tiger in Sumatra. Furthermore, the peat fires cause regional haze (smog) problems that affect public health and economies in the SE Asian region.

The data used in PEAT-CO2 show that peatlands covers 27.1 Million hectares in SE Asia (defined here as Indonesia, Malaysia, Brunei and Papua New Guinea), or 10% of the total land area. Over 22.5 Million hectares (83%) of this are in Indonesia, with a further 2 Million hectares in Malaysia and 2.6 Million hectares in Papua New Guinea. Peat thicknesses range from less than 1 to over 12 metres; a significant fraction of peatlands are over 4 metres thick (at least 17% in Indonesia). According to PEAT-CO2 calculations the total carbon store in SE Asian peatlands is at least 42,000 Mt (assuming a carbon content of 60 kg/m^3); this estimate is likely to increase when peat thicknesses and peat characteristics are better known.

Scientists have been aware of the link between peatland development and CO_2 emissions for some time, but policy makers and peatland managers are still insufficiently aware of the global implications of local and national peatland management strategies and actions. As a result, CO_2 emissions from SE Asia's drained and burning peatlands are not yet recognized in the global climate change debate, and the major coordinated international action required to help these countries to better manage their peatlands has yet to start.

1.2 This Study and Report

The PEAT-CO2 project was started in 2005 by Delft Hydraulics in collaboration with Wetlands International and Alterra, to:

A) Demonstrate the causal links between drainage and CO_2 emissions (i.e. awareness raising);

B) Quantify the actual emissions caused by peatland drainage (i.e. research), and

C) Develop peatland management support tools with a focus on water management.

In 2005, the PEAT-CO2 project determined global CO_2 emissions from drained peatland on a regional basis, and developed a prototype of a PEAT-CO2 tool for rapid peatland management strategy assessments.

In 2006 the PEAT-CO2 project determined CO_2 emissions from SE Asia alone, using more accurate data and improved assessment methods. The results of the latter activity are presented here.

This document is a consultancy report. A scientific paper on approach and results of the study will be published in a special issue of Ecology, in 2007.

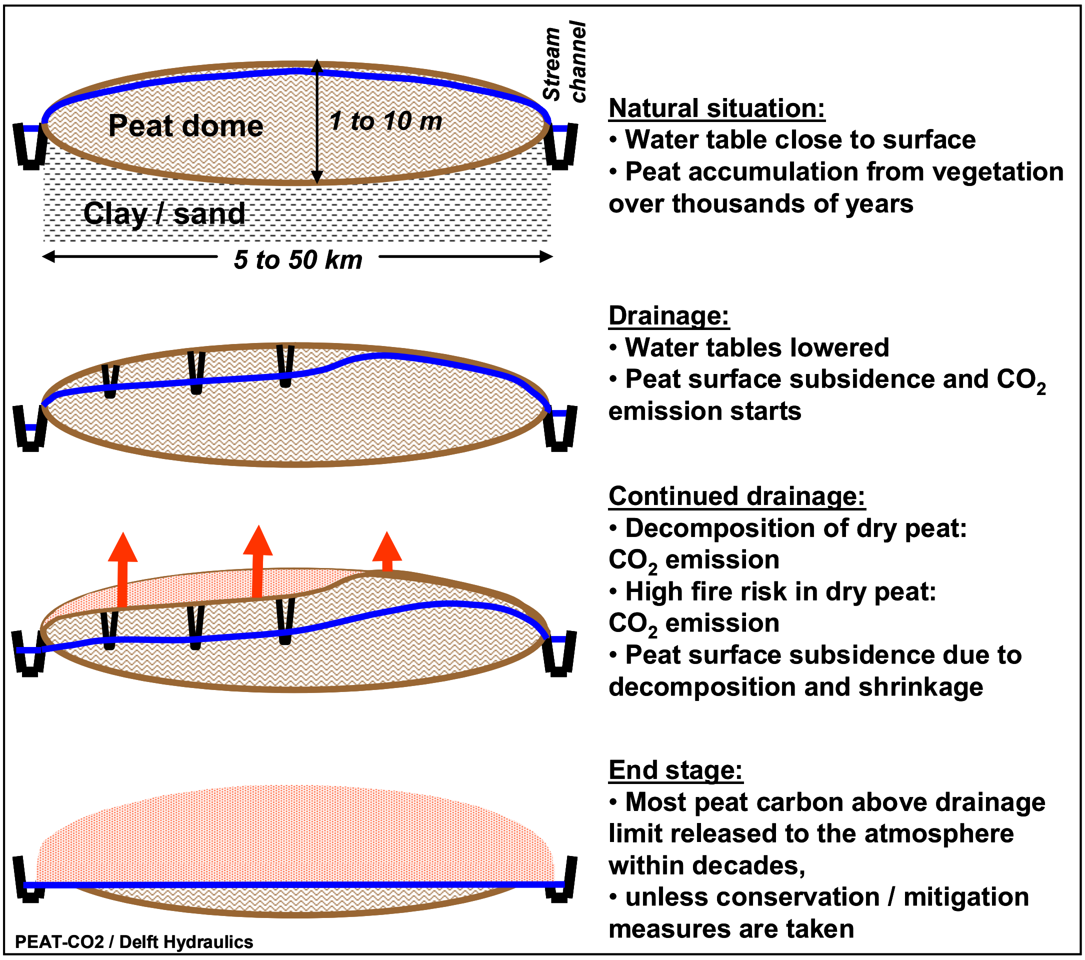

Figure 1 Schematic illustration of CO_2 emission from drained peatlands.

1.3 Acknowledgements

Within Delft Hydraulics the following persons contributed to the study and to this report:
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The following other organizations and persons were actively involved in the study presented here:

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- Alterra (Henk Wösten).
- University of Leicester (Susan Page).
- SarVision (Niels Wielaard).

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- Global Forest Watch (Fred Stolle).
- Remote Sensing Solutions (Florian Siegert).
- University of Helsinki (Jyrki Jauhiainen).

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2 Analysis approach

2.1 Analysis area

The current analysis pertains to lowland peatlands in SE Asia:

- For the purpose of this study, 4 countries in SE Asia are included which have major peat resources: Indonesia, Malaysia, Papua New Guinea and Brunei. Smaller peatland areas are found in Thailand, Vietnam, Cambodia and the Philippines. However, these are less well studied and equivalent in area and carbon volume to only a few percent of the region included. They are therefore excluded from the analysis.
- The study includes only lowland peatlands, defined as peatlands under 300m above Sea level. Some peatland areas exist in higher areas in SE Asia, however the area of these peatlands was found to be less than 3% of the peatland area, mostly in Papua (formerly Irian Jaya, in Indonesia) and Papua New Guinea, and probably represents less than 1% of the peatland carbon store as the peat deposits typically have only limited thickness.

2.2 Analysis steps

The present and future CO_2 emissions from drained peatlands in SE Asia were determined in a number of steps:

A) Develop a peatland distribution map (Figure 2).

B) Develop a peatland land use map for the year 2000 (Figure 4, Figure 5).

C) Calculate peatland areas under different land uses, by Province, State and Country, in 2000 (Table 1).

D) Determine trends in land use in peatlands, by Province (Indonesia), State (Malaysia) and Country (Brunei, PNG) (Figure 11, Table 2, Table 3, Figure 6).

E) Determine drainage depths for land use types and determine the relation between drainage depth and CO_2 emission (Table 5, Figure 12).

F) Determine CO_2 emissions from oxidation in drained peatlands by Province, State and Country, in 2000 and in the future (Figure 13, Figure 14).

G) Estimate additional CO_2 emissions from degraded and drained peatlands (Figure 16).

The basic method of analysis enabled determination of the presence of relevant parameters (presence of peat, thickness of peat, presence of drainage, depth of drainage, rate of change in drainage, etc) in GIS maps with a resolution of 1km. The Arc-GIS package was used for this. The results were than summarized in Tables by geographic analysis units, and further calculations were performed using these Tables.

2.3 Data sources

Data were obtained from several sources, including preliminary results of studies that have yet to be published.

2.3.1 Peat extent and thickness

- Peat extent and peat thickness data for Kalimantan and Sumatra, collected in field surveys over 1990-2002, were provided by Wetlands International. These data are an improvement over the FAO soil data used in earlier analyses, which has lower accuracy and detail and no thickness information. However, numbers can still be improved especially for peat thickness.
- For the remaining areas, the FAO Digital Soil Map of the World was used to determine peat percentage in soil classes, using decision rules supplied by the International Soil Reference and Information Centre (ISRIC). Peat thickness data for Papua / Irian Jaya were provided by Wetlands International. Peat thickness in other areas was estimated as described later.

2.3.2 Land use

- SE Asia land use data for the year 2000 were obtained from the GLC 2000 global land cover classification, an EU-JRC product derived from SPOT VEGETATION satellite data at a 1km resolution.
- Indonesian forest cover data for the years 1985 and 1997, and plantation concession data, were provided by the World Resources Institute (Global Forest Watch).
- Analysis results for land cover datasets (based on satellite data) over the years 2000-2005 were provided by SarVision.

2.3.3 Drainage and CO_2 emission

- Numbers for typical drainage intensity and drainage depth for different land use classes (‘cropland’, ‘mosaic cropland + shrubland’, ‘shrubland’) were estimated in consultation with the experts involved in the study presented here, all of whom have considerable field experience in peatlands in SE Asia.
- The relation between average drainage depth and CO_2 emission was provided by Dr Henk Wösten of Alterra, and is supported by a literature review (the review received additional inputs from Dr Jyrki Jauhiainen of the University of Helsinki). The relation is a simplification and needs to be further developed, but is considered applicable for a drainage depth range between 0.5m and 1m, which is the most common drainage depth range in the analysis area.

2.3.4 Emissions from peatland fires

- Data on 1997-2006 hotspot counts in Borneo were provided by Dr Florian Siegert of Remote Sensing Solutions; these data will be published separately.
- Analysis of CO_2 emissions during the 1997 peatland fires in Indonesia, published by Dr Susan Page (NATURE, 2002), is the basis for defining average CO_2 emissions over 1997-2006.
- Preliminary results on the relation between land use and fire frequency were provided by Dr Allan Spessa of the Max Planck Institute.

3 Analyses and results

3.1 Peatland distribution, thickness and carbon storage

Peatland distribution in SE Asia is shown in Figure 2. The total peatland area in SE Asia is calculated at 27.1 million hectares, or 271,000 km^2 (Table 2). To put this in perspective: this is 10% of the SE Asian land area and approximately equal to the land area of the British Isles. Indonesia alone has 22.5 million hectares, which is 12 percent of its land area and 83% of the SE Asian peatland area.

Peat thickness in Indonesia (Sumatra, Kalimantan and Papua) ranges from less than 1 metre to over 12 metres, as shown in Figure 3. While 42% of the peatland area in Indonesia is over two metres thick, these thicker peat deposits store 77% of the total peat (and carbon, approximately) deposits. It is expected similar distributions apply for the remaining peatlands of SE Asia. Peat thicknesses outside Indonesia were estimated conservatively: an average thickness of 3m was assumed for Malaysia and Brunei (assumed similar to neighbouring Kalimantan), a thickness of 1.5 metres was assumed for Papua New Guinea (assumed similar to neighbouring Papua).

Carbon storage in peatlands depends on the type of peat deposits. In SE Asia, almost all lowland peat is derived from forest vegetation and has a high wood content, however the degree of decomposition varies from peatland to peatland and within peatlands. Most studies (e.g. Page et al, 2002) consider a value in the order of 60 kgC/m^3 to be representative for SE Asian peatlands in general. Using this figure, the peat extent- and thickness data used in the current study yield a total approximate carbon storage in SE Asian peatlands of 42,000 Megatons.

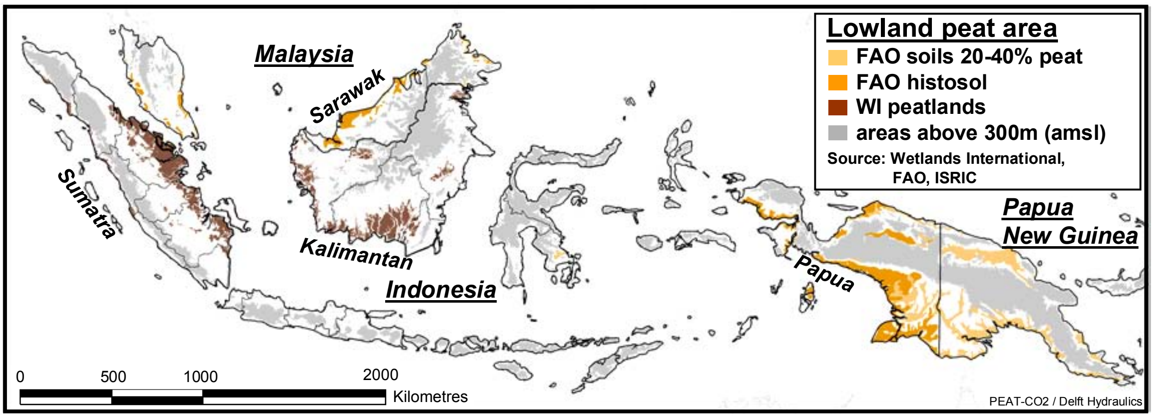

Figure 2 Lowland peat extent in SE Asia. The Wetlands International data have higher detail and accuracy than the FAO data.

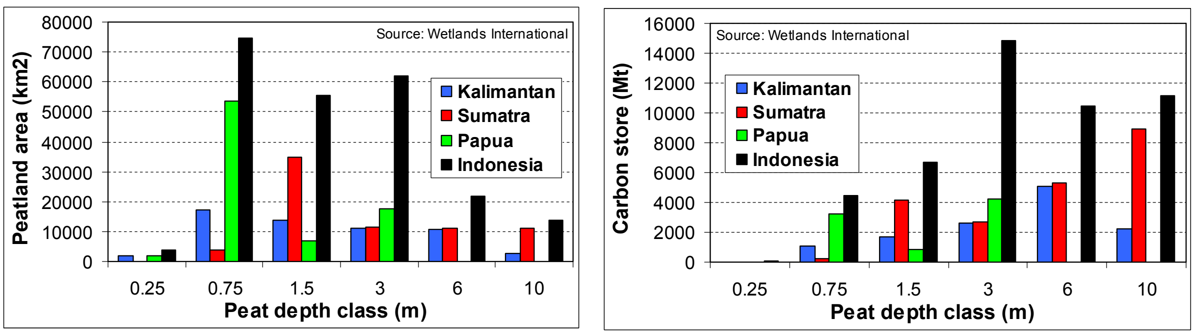

Figure 3 Peat depth/thickness classes by area. Large areas of peatland are in excess of 3 metres deep (Data: Wetlands International 2003, 2004).

3.2 Current (year 2000) and projected land use on peatlands

3.2.1 Distribution of forest cover and land use types on peatlands

Land use in the base year 2000 was derived from the GLC 2000 global land use / land cover spatial dataset. This dataset consists of (approximately) 1km cells which have been assigned specific land use classes; cells within geographic analysis units (Provinces, States and Countries) were added up by class to derive total areas for each class within each unit. This was done separately for the entire area and for lowland peatlands (under 300m elevation), by 'masking' the land use data with the peat area dataset described earlier. The results of this analysis are shown in Table 1.

In 2000, 61% of peatlands in SE Asia (that is, the countries included in the analysis: Indonesia, Malaysia, Papua New Guinea and Brunei) were covered in forest according to the GLC 2000 classification (Table 1). The same figure of 61% forest cover in 2000 applies to Indonesia. Within Indonesia, Papua had the highest remaining forest cover on peatlands (72%), Sumatra the lowest (52%).

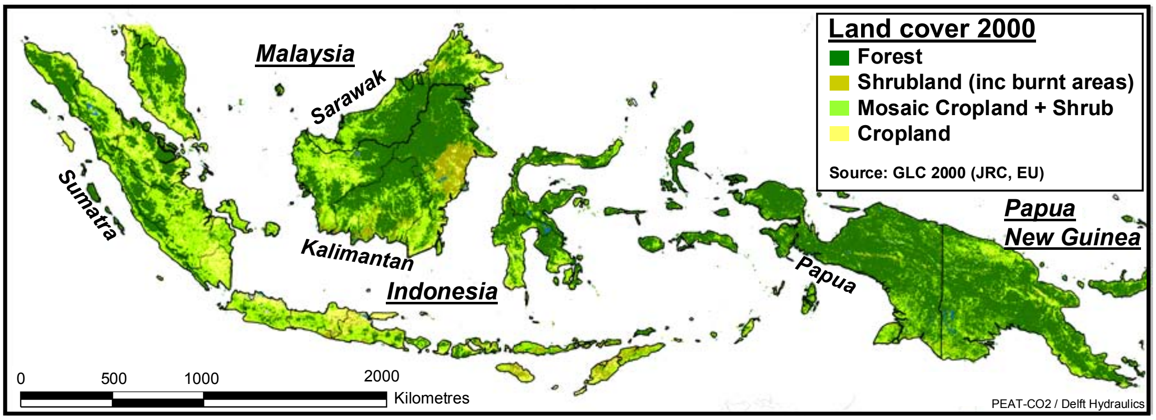

Figure 4 Land use in SE Asia as determined from GLC 2000 dataset.

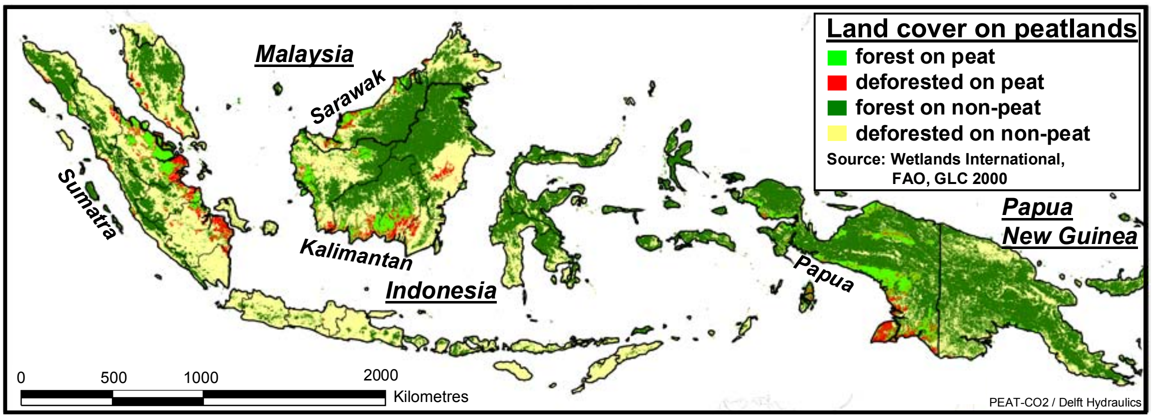

Figure 5 Forest status on peatland and non-peatland, in the year 2000.

Table 1 Peatland land use in the year 2000, as determined from the GLC 2000 global land use dataset.

GLC 2000 class:	Forest				Shrubland + burnt			Mosaic: crop+shrub			Cropland
	1	4	5	1,4,5	6	8	6,8	2	9	2,9	12
	Tree cover, broadleaved, evergreen, closed and closed to open	Tree cover, regularly flooded, Mangrove	Tree cover, regularly flooded, Swamp	**Total forest (including logged)**	Mosaics & Shrub Cover, shrub component dominant, mainly evergreen	Shrub cover, mainly deciduous, (Dry or burnt)	**Total shrubland + burnt**	Mosaic: Tree cover / Other nat. vegetation or Cropland (incl.very degraded and open tree cover)	Mosaic sof Cropland / Other natural vegetation (Shifting cultivation in maountains)	**Total mix cropland + shrub (small-scale agr.)**	Cultivated and managed, non irrigated (mixed)
	% area	% area	% area	% area	% area	% area	%area	% area	% area	%area	% area
Total Indonesia	**27**	**4**	**30**	**61**	**4**	**2**	**7**	**3**	**24**	**27**	**5**
Kalimantan	**30**	**2**	**27**	**58**	**15**	**4**	**20**	**2**	**17**	**19**	**3**
Central Kalimantan	33	1	24	57	19	2	22	2	15	18	3
East Kalimantan	29	4	11	44	22	19	42	0	9	9	5
West Kalimantan	28	3	43	74	5	1	7	2	17	19	1
South Kalimantan	14	0	4	18	15	3	18	6	45	51	14
Sumatra	**14**	**2**	**35**	**52**	**0**	**1**	**1**	**3**	**34**	**37**	**10**
D.I. Aceh	37	0	22	59	0	0	0	4	28	32	8
North Sumatera	20	1	16	36	0	2	2	3	39	42	20
Riau	14	3	49	66	0	1	1	2	24	26	7
Jambi	9	0	33	42	0	1	1	3	38	40	17
South Sumatera	11	1	14	26	0	1	2	4	57	61	12
West Sumatera	24	0	13	38	0	5	5	4	42	46	11
Papua	**36**	**9**	**27**	**72**	**0**	**1**	**2**	**4**	**20**	**25**	**1**
Malaysia	**36**	**4**	**15**	**53**	**2**	**1**	**1**	**7**	**32**	**38**	**7**
Peninsular Malaysia	37	0	0	37	0	1	1	4	47	50	13
Sabah	21	21	2	43	8	2	**10**	3	28	**31**	17
Sarawak	38	3	23	59	2	1	**2**	9	26	**35**	4
Brunei	**39**	**6**	**39**	**84**	**3**	**1**	**4**	**1**	**9**	**10**	**2**
Papua N. Guinea	**38**	**5**	**19**	**61**	**0**	**1**	**1**	**4**	**32**	**35**	**3**
SE ASIA	**29**	**4**	**28**	**61**	**4**	**2**	**5**	**4**	**26**	**29**	**5**

Source: GLC 2000

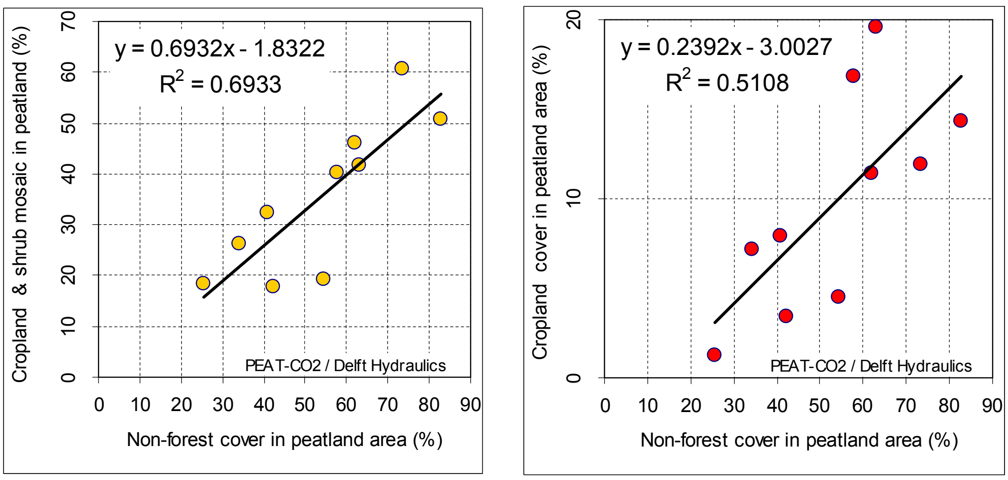

Figure 6 Comparison of peatland land use in Indonesian Provinces yields insight in land use development trends. Areas are expressed as a percentage of total peat area by Province, as in Table 1.

Left: the area of 'cropland & shrubland mosaic' (i.e. small-scale agriculture, more or less) increases proportionally with the total deforested area.
Right: the area of 'cropland' (i.e. large-scale agriculture, more or less) also increases with the total deforested area, but the fraction cropland increases faster than other land uses.

3.2.2 Trends and projections in land use changes on peatlands

Deforestation rate on peatlands

The tropical peat swamp forests are under tremendous pressure from agriculture/silviculture development and logging. Trends in forest cover in SE Asia were derived from changes between 1985 (World Resources Institute data) and 2000 (GLC 2000 data), as shown in Table 2. Over this period, peatlands were deforested at rate of 1.3% per year on average; the highest value is found in East Kalimantan (2.8%/y), the lowest in Papua (0.5%/y). As the 1985 data were only available for Indonesia, trend analysis for the other countries is based on comparison with Indonesia and results are less accurate. Trends for SE Asia were also verified for 2000-2005 using tentative SarVision data (Table 3); it appears the average deforestation rate in peatlands in SE Asia over 2000-2005 is 1.5%/y (of forest cover in 2000). Allowing for the difference in reference years (1985 and 2000), these percentages are very similar and suggest that deforestation on peatlands has continued at a high rate over the past 20 years.

According to Table 2, 10.6 million hectares (39%) of peatland in SE Asia was deforested in 2000. Accounting for continued deforestation at a rate of 1.5%/y, the deforested peatland area in 2006 is around 45% of total peatland area, or 12.1 million hectares.

Table 2 Basic data for PEAT-CO2 calculations, including the rate of deforestation in lowland peatlands.

Note that the Global Forest Watch forest cover data for 1997 (not shown) indicate lower forest cover than the GLC 2000 data used in the analysis. The rate of deforestation used in PEAT-CO2 analyses is therefore considered conservative.

Basic data for PEAT-CO2 SE Asia calculations	Total Area	Lowland peat area	Peatland % of total area	Total forest cover 1985	2000	Forest loss 1985-2000	Lowland peatland forest cover 1985	2000	Forest loss 1985-2000
	ESRI km2	WI+FAO km²	%	GFW %	GLC2000 %	%/y	GFW %	GLC2000 %	%/y
Indonesia	**1919317**	**225234**	**12**	**67**	**59**	**-0.7**	**81**	**61**	**-1.3**
Kalimantan	**531506**	**58379**	**11**	**72**	**57**	**-1.2**	**87**	**58**	**-1.9**
Central Kalimantan	154829	30951	20	69	63	-0.6	90	57	-2.2
East Kalimantan	193351	6655	3	88	65	-1.9	85	44	-2.8
West Kalimantan	147527	17569	12	61	50	-0.9	92	74	-1.2
South Kalimantan	35799	3204	9	45	26	-1.5	41	17	-1.6
Sumatra	**464301**	**69317**	**15**	**52**	**40**	**-1.0**	**78**	**52**	**-1.8**
D.I. Aceh	56515	2613	5	71	62	-0.8	87	59	-1.8
North Sumatra	71316	3467	5	40	36	-0.4	76	36	-2.6
Riau	92141	38365	42	69	48	-1.7	87	66	-1.4
Jambi	48518	7076	15	56	44	-1.0	67	42	-1.7
South Sumatra	84198	14015	17	38	20	-1.5	66	26	-2.6
West Sumatra	41585	2096	5	68	62	-0.5	69	38	-2.1
Papua	**411649**	**75543**	**18**	**84**	**80**	**-0.3**	**80**	**72**	**-0.5**
Other Indonesia	**511,860**	**21995**	**4**					**61**	
Malaysia	**327291**	**20431**	**6**				**78***	**53**	**-1.8***
Peninsular M.	131205	5990	5				78*	37	-2.8*
Sabah	72767	1718	2				86*	43	-2.9*
Sarawak	123320	12723	10				76*	59	-1.1*
Brunei	**5772**	**646**	**11**				**85***	**84**	**-0.2***
Papua New Guinea	**399989**	**25680**	**6**				**80***	**61**	**-1.3***
SE Asia	**2652370**	**271991**	**10**					**61**	

* Estimated

Comparison of forest cover and trends on peatlands and non-peatlands

The year 2000 forest cover on peatlands in SE Asia is similar to that in non-peatlands (according to the GLC 2000 dataset): 61% vs 59% in Indonesia, 51% vs 56% in Malaysia, 82 vs 80% in Papua New Guinea (Table 1). However, the deforestation rate in peatlands over 1985-2000 was almost double that in non-peatlands: 1.3%/y vs 0.7%/y in Indonesia (Table 2). Tentative findings by SarVision suggest that the deforestation rate in peatlands is stable since 2000 to 1.5%/y (Table 3, Figure 7), while that in non-peatlands is lower (0.85%/y) and has decreased in recent years. As a result, deforestation of peatlands amounted to 25% of all deforestation in SE Asia in the year 2005 (Table 3).

In relative terms, a greater oil palm and timber plantation area is planned on peatlands than on non-peatlands: 27% of concessions are planned on the 12% land surface that is peatland in Indonesia. No concession data were available for Malaysia at the time of this study, but the percentage of oil palm plantations on peatlands in Sarawak may be even greater (Figure 8).

Land use developments within deforested areas

Projections of land use change within deforested areas were based on the analysis of the relative areas of GLC 2000 classes ('cropland', 'cropland + shrubland' and 'shrubland') within the deforested areas of Indonesian Provinces (Figure 6). Linear relations derived as shown in Figure 6 were applied to the deforested area in the projections, at 5-year time steps. The advantage of this approach is transparency, the drawback is that once 100% of the peatland within a Province or Country is deforested, its land use is fixed. The area of 'cropland', interpreted as large-scale agriculture which has the highest drainage density and the deepest drainage, will not exceed 21% of the total area. The maximum area of 'mosaic cropland + shrubland', interpreted as small-scale agriculture with lower drainage density and depth, is 68% of the total deforested area. In actual fact the very large-scale and intensively drained palm oil and timber plantations concessions alone already cover 27% of the peatland area in Indonesia; a similar percentage may apply in Malaysia). The approach is therefore considered conservative: the future drainage intensity in deforested areas is probably underestimated.

No projections were developed for the degree of degradation within forest areas, due to logging (legal and illegal) and due to regional drainage impacts of plantations, for lack of data on this issue. This degradation is known to be rapidly increasing and to be accompanied by drainage and fires, and hence by CO_2 emissions. Not including forest degradation in the PEAT-CO2 assessment inherently leads to a further underestimation of drained area in peatlands in this study.

Table 3 Recent deforestation rates on peatland and non-peatland, for SE Asia, as determined by SarVision. These are tentative results, for Insular South East Asia, of a systematic forest cover monitoring system for tropical forest regions developed by SarVision. The system uses SPOT Vegetation satellite images (work on integration of MODIS and MERIS is ongoing) and provides forest cover updates on a 3-monthly basis since 1999. Results have been overlain on the peat extent maps used in the PEAT-CO2 SE Asia study, to identify trends after the year 2000 (the PEAT-CO2 trend analysis covers the years 1985 and 2000).
Note that the forest determined by SarVision are somewhat different from the ones used in the current study, because SarVision has included part of Thailand and the Philippines in the analysis. This hardly affects the forest cover on peatlands, but it does affect the total forest area. Also, the definition of 'forest cover' used by SarVision appears to be somewhat different from the GLC 2000 definition.

Deforestation rate (2000 - 2005) for Total Forest and Peat Swamp Forest in Insular SE Asia							
Year	**Total Forest**	**Total Forest Loss**		**Peat Swamp Forest**	**Peat Swamp Forest Loss**		
	km^2	km^2/y	% of total forest	km^2	km^2/y	% of peat forest	% of total forest loss
2000	1869762	22430	1.20	165839	2201	1.33	9.81
2001	1855477	14285	0.76	164036	1803	1.09	12.62
2002	1830239	25237	1.35	160685	3351	2.02	13.28
2003	1819106	11133	0.60	158846	1838	1.11	16.51
2004	1806412	12693	0.68	155863	2983	1.80	23.50
2005	1796804	9609	0.51	153471	2392	1.44	24.90
Average:		15898	0.85		2428	1.46	16.77
Source: SarVision							

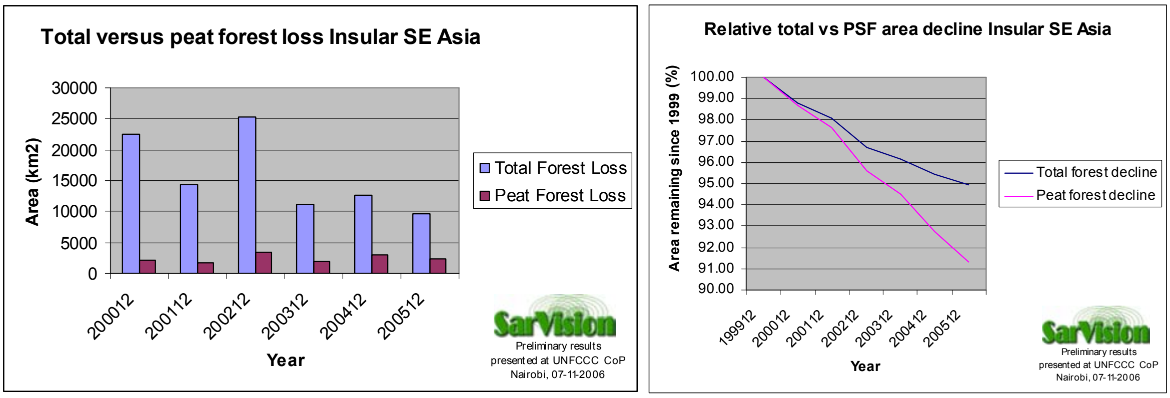

Figure 7 Graphic representation of figures shown in the table above.

Figure 8 Deforestation data for Sarawak (provided by SarVision) show that around 50% of forest lands cleared from 1999 to June 2006 (red areas) are located on peat lands (brown areas). Field observations and rapid assessment of satellite data suggest that many of these areas are cleared for large scale oil palm plantations.

3.2.3 Timber and oil palm plantation concessions on peatlands

Knowing the area of concessions on peatlands is important for quantification of potential future CO_2 emissions from peatlands.

There are three main types of concessions in SE Asian peatlands: logging concessions (HPH in Indonesia), timber plantation concessions much of which is acacia pulp wood plantations for paper production (HTI in Indonesia), and oil palm plantation concessions (BHP in Indonesia). Of these, especially the timber and oil palm plantation concessions on peatlands require intensive drainage.

Logging in peatlands (legally in HPH concessions, and illegally) is often accompanied by construction of transport canals, which also drain the peatlands. This drainage is often less deep than in plantation areas, causing less CO_2 emission unless accompanied by fires by unit area, but total emissions may still be significant as the areas involved are vary large.

No concession data were available for Malaysia and Papua New Guinea. Concession data for the main peatland areas in Indonesia (Sumatra, Kalimantan and Papua), provided by the World Resources Institute, were available to determine the planned or potential areas of various land uses on peatlands (Table 4). These data cover both existing and planned developments.

According to the concession data available, 27% of both timber and oil palm concession areas in Indonesia are on peatlands. The total oil palm concession area on peatlands is 28,009 km^2 (2.8 million hectares), the total timber concession area 19,923 km^2 (2 million hectares). Both concession types are concentrated in Sumatra and Kalimantan, with only a small oil palm concession area in Papua. Oil palm plantation concessions cover 14% of the total peatland area, oil palm + timber plantation concessions 23% (Table 2). This is not including state-owned and co-operative plantations, other (not BHP or HTI) agricultural developments (e.g. the Mega Rice Project in Central Kalimantan) and drainage schemes for logging purposes (legal and illegal). In addition to the plantation concessions, 12% of peatlands is earmarked as logging concession (HPH).

There are indications that the concession data are not very accurate: overlays between 2 or even 3 concession types are found in some areas. Also, it should be noted that these concession data represent only part of the total current + planned oil palm and timber plantations; co-operative plantations and state plantations appear not to be included. It is concluded that the concession data provide a useful estimate of the planned area of timber and oil palm plantations on peatlands, but better data are needed.

With the concession data available it is not possible to precisely determine the current areas of these land uses. However until better data are available we can only assume that the percentage of oil palm and timber plantations currently on peatlands is similar to the planned percentages. We therefore assume that some 25% of current oil palm and timber plantations are on peatlands. The current percentage in Indonesia may be higher: tentative inspection of satellite images of the Province of Riau indicates that at least 50%, and probably more than 75% of the 800,000 ha of oil palm concession in that Province Figure 10) is already developed. Assuming 75% is developed, these 600,000 hectares of existing oil palm plantations alone represent 15-20% of the present total palm plantation area in the country (3.5 to 4 million hectares according to most estimates).

An interesting assessment of the expected rate of development of oil palm plantations is provided in a report by the Indonesian Ministry of Forestry in co-operation with the European Union (Sargeant, 2001): *"The world demand for palm oil is forecast to increase from its present 20.2 million tonnes a year to 40 million tonnes in 2020. If this demand is to be met, 300 000 ha of new estates will need to be planted in each of the next 20 years. We predict that by far the largest slice of this new land will come from within Indonesia where labour and land remain plentiful. And we expect that Sumatra,* *with its relatively well-developed infrastructure and nucleus of skilled labour, will absorb 1.6 million hectares of this expansion. It is inevitable that most new oil palm will be in the wetlands, as the more 'desirable' dry lands of the island are now occupied. We expect that of the new areas, half will be developed by estates and half by smallholders."* There are two important aspects to this assessment:

1. It suggests that over 50% of oil palm plantations, at least in Sumatra (but similar considerations apply in parts of Kalimantan), will be developed on peatlands. This is more than is suggested by concession data available to the study.
2. It suggests that half of the plantations will be developed by smallholders, which may not be represented in the concession data.

As projections for global oil palm demand have been rising in recent years, with biofuel as an increasingly important use, the assessment above should probably be considered conservative at present (5 years later). It is concluded that a figure of 25% oil palm plantations may be a realistic estimate for current conditions, but is a conservative estimate for future conditions.

Table 4 Concessions on peatland in Indonesia.

Concessions in Indonesia										
			Logging		**Timber plantation**		**Oil Palm plantation**			
		Lowland peat area	HPH total~	HPH on lowland peat~	HTI total~	HTI on lowland peat~	BHP total~	BHP on lowland peat~	HTI+ BHP total~	HTI+ BHP on lowland peat~
		km²	*km²*	*km²*	*km²*	*km²*	*km²*	*km²*	*km²*	*km²*
Kalimantan			**124217**	**4451**	**27274**	**3104**	**50255**	**14725**		
Sumatra			**23601**	**6295**	**33544**	**11827**	**49513**	**12494**		
Papua			**95902**	**13686**	**14036**	**4992**	**3610**	**790**		
Total Kal + Sum + Pap			**243720**	**24432**	**74854**	**19923**	**103378**	**28009**	**178232**	**47932**
					as a percentage of total plantation area					
Kalimantan				**4**		**11**		**29**		
Sumatra				**27**		**35**		**25**		
Papua				**14**		**36**		**22**		
Total Kal + Sum + Pap				**10**		**27**		**27**		**27**
		km²	*% total area*	*% peat area*	*% total area*	*% peat area*	*% total area*	*% peat area*	*%peat area*	*%peat area*
Kalimantan		**58379**	**23**	**8**	**5**	**5**	**9**	**25**	**15**	**31**
	C. Kalimantan	30951	28	5	2	2	18	41		
	E. Kalimantan	6655	31	13	6	9	6	16		
	W. Kalimantan	17569	11	12	7	11	6	5		
	S. Kalimantan	3204	16	0	6	0	7	3		
Sumatra		**69317**	**5**	**9**	**7**	**17**	**11**	**18**	**18**	**35**
	D.I. Aceh	2613	11	5	6	0	6	40		
	N. Sumatera	3467	3	1	5	0	3	18		
	Riau	38365	8	13	16	20	22	23		
	Jambi	7076	8	9	5	2	17	8		
	S. Sumatera	14015	1	1	10	29	5	6		
	W. Sumatera	2096	8	11	1	2	22	23		
Papua		**75543**	**23**	**18**	**3**	**7**	**1**	**1**	**4**	**8**
Total Kal + Sum + Pap		**204156**	**16**	**12**	**5**	**10**	**7**	**14**	**11**	**23**
Data sources:		*World Resources Institute / Global Forest Watch (concession areas)*								
		Wetlands International (peatland Kalimantan, Sumatra)								
		FAO / ISRIC (peatland Irian Jaya)								
~'total' area is total area of Province (or Region/Country); 'lowland peat' area is peat area under 300m within that Province										

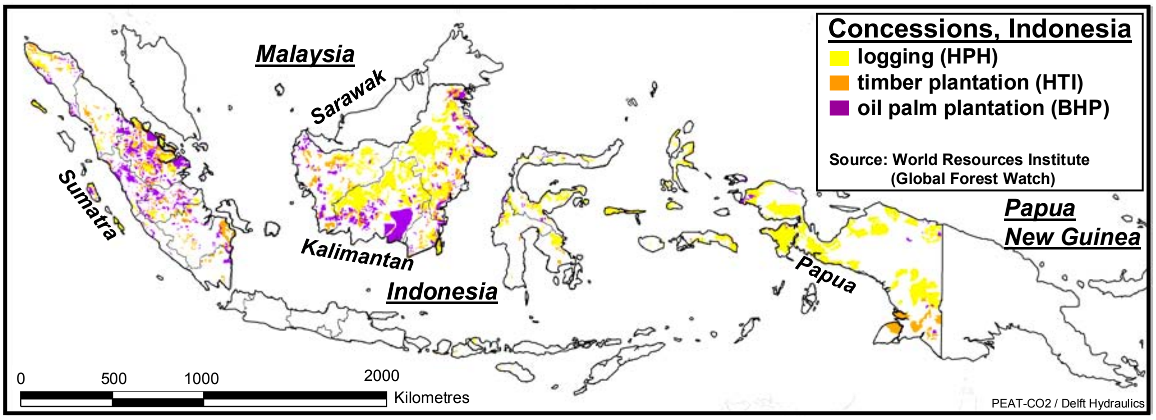

Figure 9 Concessions in Indonesia (Source: World Resources Institute / Global Forest Watch).

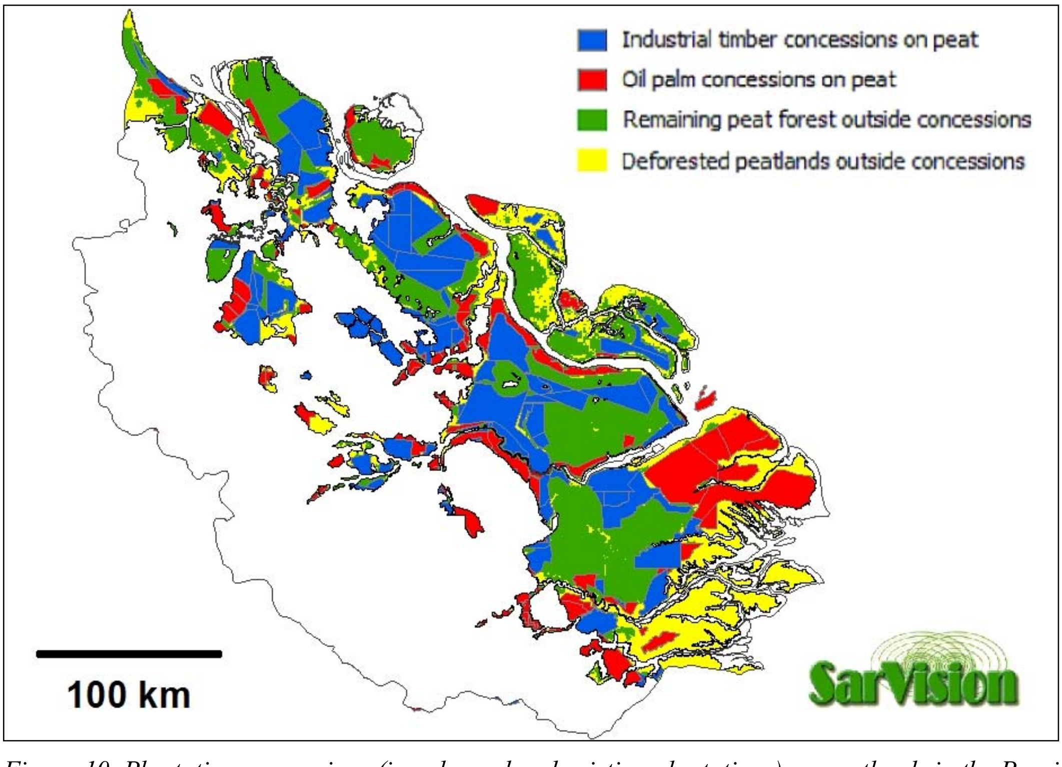

Figure 10 Plantation concessions (i.e. planned and existing plantations) on peatlands in the Province of Riau (Sumatra). Based on concession data provided by the Riau Plantation Service (2004). According to these data, 37.7% (801,555 ha) of existing plus planned oil palm plantations in Riau are located on peat lands. Logging concessions (HPHs) are not shown but cover much of the area marked as 'remaining forest outside concessions). It should be noted that the data provided by the Riau Plantation Service are approximate.

3.2.4 Result: land use projections for SE Asian peatlands

Projections of deforestation rate were developed by simply continuing the rate of forest loss between 1985 and 2000 into the future, until all peatland is fully deforested, per Province (Indonesia) or country. The numbers were then added up to derive overall deforestation projections for larger geographic units, as shown in Figure 11.

Predicting future land use developments by projecting past trends is a crude simplification of actual developments of course, but it can be argued in this case that it is realistic, even conservative in some respects, to assume current rates of deforestation and drainage to continue:

- Deforestation rates have continued at a constant rate (on average) for 20 years, as indicated by comparison between deforestation rates over 1985-2000 and over 2000-2005.
- The rate of deforestation in peatlands was shown to be almost twice that in non-peatlands. With non-peatland lowland areas being largely deforested in most of Indonesia, the remaining forested peatlands and mountain ranges are increasingly important sources of timber. Of these, peatlands are the more attractive as they are more easily accessible and are seen to allow agricultural development.
- No policy has been implemented to specifically conserve and protect peatlands forests. The Indonesian Presidential Decree No. 32/1990, stipulates that peat areas deeper than 3 meters should not be developed, but this decree has generally not been enforced. Moreover, this policy warrants review as it would allow reclamation and drainage of the outer zone of a peat dome with a depth of less than 3 meters. This would lead to subsidence of the deeper parts of the dome, a process that could continue until the entire dome would be lower than 3 meters and thus “eligible” for reclamation (Silvius & Suryadiputra, 2005).
- The area of gazetted conservation reserves in peatlands is unclear but is estimated at less than 10 or even 5% of the total peatland area. Moreover, all peatland conservation areas in western Indonesia are being subject to degradation from logging, drainage and fires (e.g. Berbak and Sembilang National Parks in Sumatra, Tanjung Putting and Sebangau National Parks in Central Kalimantan). Almost all remaining peat swamp forests in Malaysia have been subject to degradation from logging and often also drainage.

As noted earlier (Section 3.2.2), the current baseline and projection method limit the area of large intensively drained croplands (including plantations) to 21% of the peatland area after deforestation is completed. We also found that the concession area of timber and oil palm plantations alone covers 23% of peatlands in Indonesia, and that additional plantations outside these concessions exist and more are planned. The projected cropland area should thus be considered conservative.

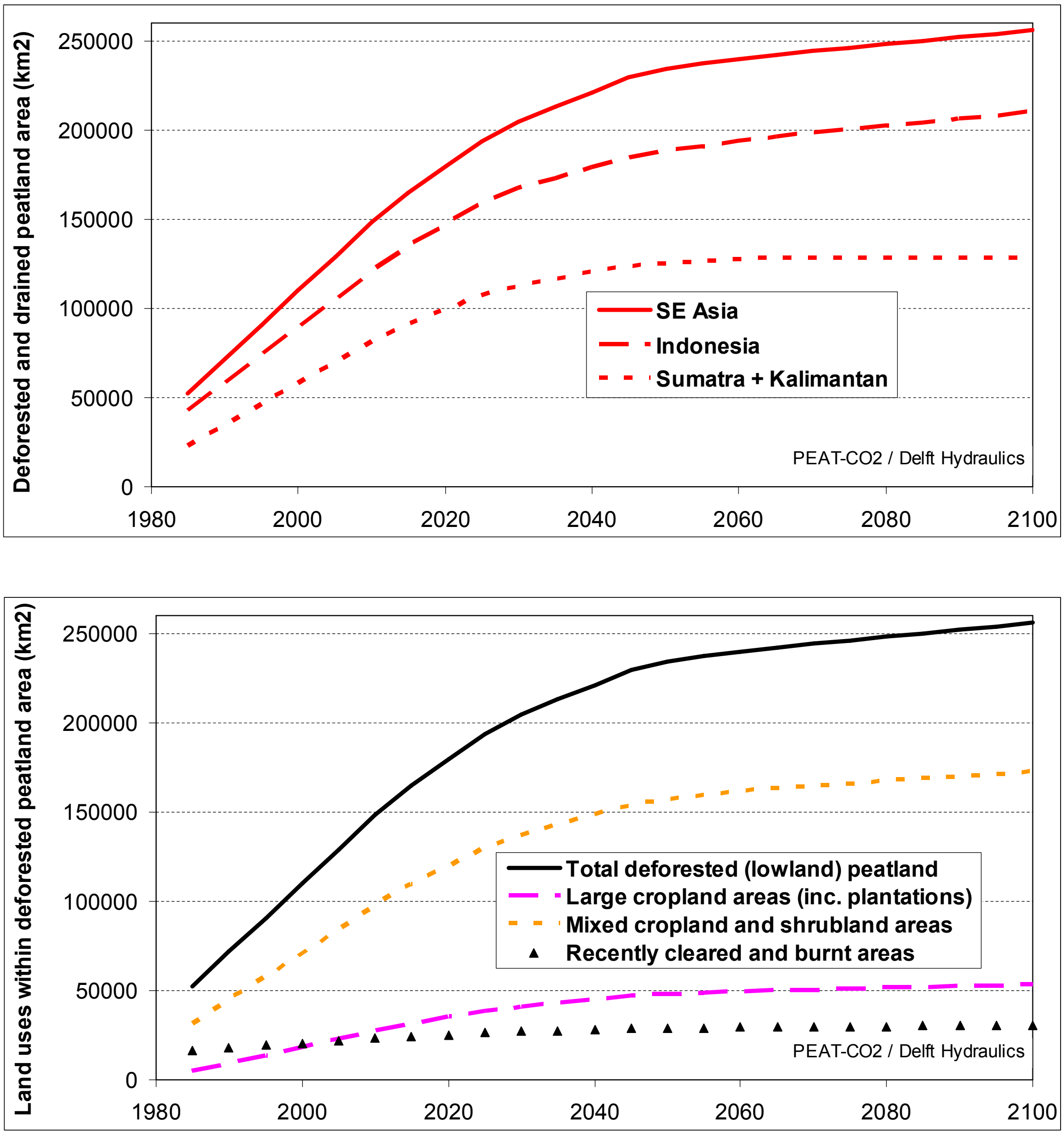

Figure 11 Current trends and future projections of deforestation in lowland peatlands in SE Asia.

Land use classes are derived from the GLC 2000 classification, see Table 1.

3.3 Current and projected CO_2 emissions from oxidation in drained peatlands

Emissions from drained peatlands were determined in the following steps:

1. Drained areas within land use classes, and drainage depths, were estimated in consultation with peatland experts (Table 5). Estimates of minimum and maximum values were averaged to determine a 'likely' value. Estimates are considered conservative: e.g. average drainage depths well over 1 metres (up to 3 metres in some cases) are reported for many oil palm and pulp wood (acacia) plantations as well as degraded non-used areas (e.g. the Ex-Mega Rice area in Central Kalimantan) whilst a likely value of 0.95m was used. Some observers report that nearly 100% of the area within the 'mixed cropland / shrubland' and 'shrubland' land use classes should be considered drained whilst values of 88% and 50% were applied.
2. Drainage depths were linked to CO_2 emissions (in tonnes/ha/year) using a relation provided by Henk Wösten (Alterra), shown in Figure 12. This relation was derived primarily from the most reliable source of information: long term monitoring of peat subsidence in drained peatlands, combined with peat carbon content and bulk density analysis to filter the contribution of compaction from the total subsidence rate - the remainder is attributed to CO_2 emission (Wösten et al, 1997; Wösten and Ritzema, 2001). This assessment method is accurate but yields only few measurement points; for lack of a large enough population of observations a linear relation between drainage depth and CO_2 emission was fitted through the data whereas the actual relation is known to be non-linear. In the drainage depth range most common in SE Asian peatlands, between 0.5 and 1 metre, the relation is supported by results from numerous gas emission monitoring studies in peatlands (Figure 12, Table 6).
3. The resulting typical emissions for land use classes were applied to that the total area of each class in each Province/State/Country, for the drained area assumed (Table 5).

Total emissions per Province/State/Country were calculated for past, current and projected land uses, as shown in Figure 13. Emissions in 2005 were calculated to be between 355 and 874 Mt/y, with a likely value of 632 Mt/y. Applying the land use projections proposed earlier (Section 3.2.4), emissions increase every year for the first decades after 2000. However, as shallow peat deposits become depleted, and the drained peatland area therefore diminishes, emissions are predicted to peak sometime between 2015 and 2035, between 557 and 981 Mt/y (likely value 823 Mt/y), and are predicted to then steadily decline. As the deeper peat deposits will take much longer to be depleted, significant CO_2 emission would continue beyond 2100.

It should be noted that 'forest' is considered non-drained for the purpose of this assessment, while it is known that many remaining forests are affected by drainage: by neighbouring plantations and agricultural areas, by roads, by canals constructed for transport of illegal logs, and by forest fires that create depressions that act as drains within the peatland hydrological system. Those forests are likely to have become net sources of carbon emissions to the atmosphere, instead of the carbon sinks and stores they are in their natural state. This is another reason to consider the calculated CO_2 emission from peatlands conservative. A further reason is that above-ground biomass losses during deforestation are not included in the analysis.

Table 5 Parameters used in CO_2 emission calculations.

			minimum	likely	maximum
Step A: Drained area (within land use class)	Large croplands, including plantations	%	100	100	100
	Mixed cropland / shrubland: small-scale agriculture	%	75	88	100
	Shrubland; recently cleared & burnt areas	%	25	50	75
Step B: Drainage depth (within land use class)	Large croplands, including plantations	m	0.80	0.95	1.10
	Mixed cropland / shrubland; small-scale agriculture	m	0.40	0.60	0.80
	Shrubland; recently cleared & burnt areas	m	0.25	0.33	0.40
Step C: A relation of 0.91 t/ha/y CO_2 emission per cm drainage depth in peatland was used in calculations.					
Step D: CO2 emissions (calculated from A, B, C)	Large croplands, including plantations	t/ha/y	73	86	100
	Mixed cropland / shrubland: small-scale agriculture	t/ha/y	27	48	73
	Shrubland; recently cleared & burnt areas	t/ha/y	6	15	27

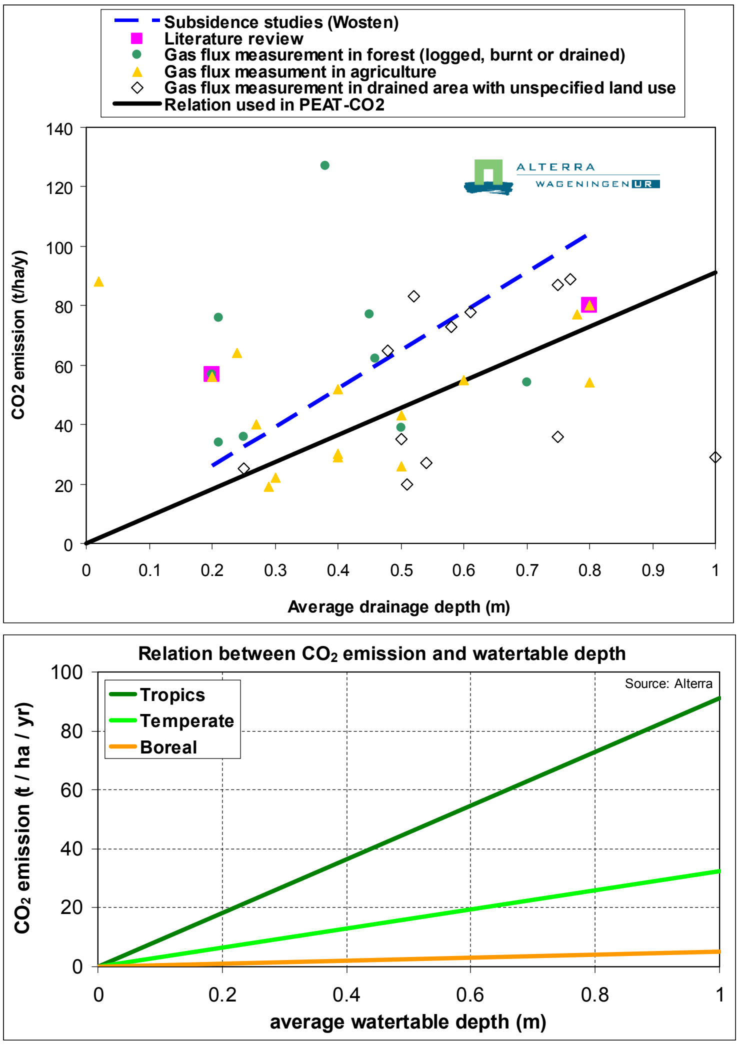

Figure 12 Relation between drainage depth and CO_2 emission from decomposition (fires excluded) in tropical peatlands, as used in PEAT-CO2. Note that the average water table depth in a natural peatland is near the soil surface (by definition, as vegetation matter only accumulates to form peat under waterlogged conditions).
Top: The relation for tropical areas, including SE Asia, is based both on long-term subsidence studies and shorter-term gas flux emission studies applying the 'closed chamber method' (see Table 6). Results of different methods were combined to derive a linear relation. This relation needs to be further developed, as it should be non-linear: in reality CO_2 emissions are known to be limited with drainage depths up to 0.2m-0.3m. Also, CO_2 emissions for a given drainage depth will change over time. However, use of a constant and linear relation is deemed acceptable for long-term assessments and for drainage depths between 0.25m and 1.1m as applied in this study.
Bottom: Tropical drained peatlands have far higher CO_2 emissions than temperate and boreal drained peatlands at the same drainage depth, because of higher decomposition rates in permanently hot and humid climates. Moreover, peatlands in SE Asia are generally drained to much greater depths than is common in temperate and boreal peatlands.

Table 6 Literature review of CO_2 emissions related to drainage depth for different land use types.

Provided by Dr Henk Wösten of Alterra.

Author	**Measurement method**	**Country / region**	**land use**	**drainage depth**	**drainage duration**	**CO_2-em. (tonnes /ha/year)**
Ali et al. 2006	gas flux measurement with closed chamber method	Jambi, Indonesia	Logged forest	25	variable	36
Ali et al. 2006	gas flux measurement with closed chamber method	Jambi, Indonesia	Recently burned and cleared forest	46	variable	62
Ali et al. 2006	gas flux measurement with closed chamber method	Jambi, Indonesia	Settled agriculture	78	variable	77
Armentano and Menges 1986	from literature: Tate (1980); Stephens & Stewart (1976); Rigg & Gessel (1956); Broadbent (1960)	Florida, Pacific coast	Pasture/Forestry	20		57
Armentano and Menges 1986	from literature: Tate (1980); Stephens & Stewart (1976); Rigg & Gessel (1956); Broadbent (1960)	Florida, Pacific coast	Crops	80		80
Barchia and Sabiham 2002	gas flux measurement with closed chamber method	Central Kalimantan	Rice fields at 3 locations	10		4
Furukawa et al. 2005	gas flux measurement with closed chamber method	Jambi, Indonesia	drained forest	18 cm	constant	86
Furukawa et al. 2005	gas flux measurement with closed chamber method	Jambi, Indonesia	cassava field	24 cm	constant	64
Furukawa et al. 2005	gas flux measurement with closed chamber method	Jambi, Indonesia	upland paddy field	13 cm	constant	73
Furukawa et al. 2005	gas flux measurement with closed chamber method	Jambi, Indonesia	lowland paddy field	5 above ground surface		10
Hadi et al. 2001	gas flux measurement with closed chamber method	South Kalimantan	Secondary forest	0	constant	45
Hadi et al. 2001	gas flux measurement with closed chamber method	South Kalimantan	Paddy field	2	constant	88
Hadi et al. 2001	gas flux measurement with closed chamber method	South Kalimantan	Secondary forest	38		127
Hadi et al. 2001	gas flux measurement with closed chamber method	South Kalimantan	Paddy field	0		51
Hadi et al. 2001	gas flux measurement with closed chamber method	South Kalimantan	Rice-soybean rotation field	18		74
Inubushi et al. 2003 + Inubushi et al. 2005	gas flux measurement with closed chamber method	South Kalimantan	Abandoned upland crops field	0		36
Inubushi et al. 2003 + Inubushi et al. 2005	gas flux measurement with closed chamber method	South Kalimantan	Abandoned paddy fields	20		56
Inubushi et al. 2003 + Inubushi et al. 2005	gas flux measurement with closed chamber method	South Kalimantan	Secondary forest	18		44
Jauhiainen et al. 2005	gas flux measurement with closed chamber method	Sebangau river catchment, Kalimantan, Indonesia	peat swamp forest	Ave -17 cm, Max. 24 cm, Min. -75 cm, Median -10 cm	variable	35
Jauhiainen et al. 2004	gas flux measurement with closed chamber method	Sebangau river catchment, Kalimantan, Indonesia	selectively logged forest (near tree)	Ave -21 cm, Max. 10 cm, Min. -67 cm, Median -15 cm	variable	76
Jauhiainen et al. 2004	gas flux measurement with closed chamber method	Kalimantan, Indonesia	cleared burned area (high surface)	-19	variable	23
Jauhiainen et al. 2004	gas flux measurement with closed chamber method	Kalimantan, Indonesia	cleared burned area (depression)	Ave 1 cm, Max. 46 cm, Min. -49 cm, Median -6 cm	variable	28
Jauhiainen et al. 2004	gas flux measurement with closed chamber method	Kalimantan, Indonesia	Clear felled but recovering forest	Ave -21 cm, Max. 10 cm, Min. -67 cm, Median -15 cm	variable	34

Author	Measurement method	Country / region	land use	drainage depth	drainage duration	CO_2-em. (tonnes /ha/year)
Jauhiainen et al. 2004	gas flux measurement with closed chamber me.	Kalimantan, Indonesia	farm field	Ave -29 cm, Min. -72 cm, Max. – 5 cm, Median -24 cm	Median -24 cm	19
Jauhiainen et al. 2001	gas flux measurement with closed chamber me.	Central Kalimantan,	Drained peat and Hollow	0		17
Jauhiainen et al. 2001	gas flux measurement with closed chamber me.	Central Kalimantan	Drained peat	50		26
Jauhiainen et al. 2001	gas flux measurement with closed chamber me.	Central Kalimantan	Hummock	50		43
Jauhiainen et al. 2001	gas flux measurement with closed chamber me.	Central Kalimantan	Hollow	40		52
Jauhiainen 2006	gas flux measurement with closed chamber me.	Central Kalimantan		25		25
Jauhiainen 2006	gas flux measurement with closed chamber me.	Central Kalimantan		50		35
Jauhiainen 2006	gas flux measurement with closed chamber me.	Central Kalimantan		75		36
Jauhiainen 2006	gas flux measurement with closed chamber me.	Central Kalimantan		100		29
Melling et al. 2005	gas flux measurement with closed chamber m.	Sarawak, Malaysia	forest	45 cm	variable	77
Melling et al. 2005	gas flux measurement with closed chamber method	Sarawak, Malaysia	oil palm	60 cm	variable	55
Melling et al. 2005	gas flux measurement with closed chamber method	Sarawak, Malaysia	sago	27 cm	variable	40
Murayama and Bakar 1996 a+b	gas flux measurement with closed chamber method	Western Johore, Malaysia	forest	50		39
Murayama and Bakar 1996 a+b	gas flux measurement with closed chamber method	Western Johore, Malaysia	oil palm plantation	80		54
Murayama and Bakar 1996 a+b	gas flux measurement with closed chamber method	Western Johore, Malaysia	pineapple field	40		30
Murayama and Bakar 1996 a+b	gas flux measurement with closed chamber method	Central Selangor, Malaysia	maize field	40		29
Murayama and Bakar 1996 a+b	gas flux measurement with closed chamber method	Central Selangor, Malaysia	fallow peat	30		22
Vijarnsorn et al. and Ueda et al.	gas flux measurement with closed chamber method	Thailand	forest	70		54
Wösten et al. 1997 and Wösten and Ritzema 2001	Measurements of subsidence and soil characteristics	Western Johore and Sarawak	agriculture	An average water level drawdown (by drainage) of 10 cm results in 1cm/year of subsidence and yields 13t/y of CO_2 emission.		

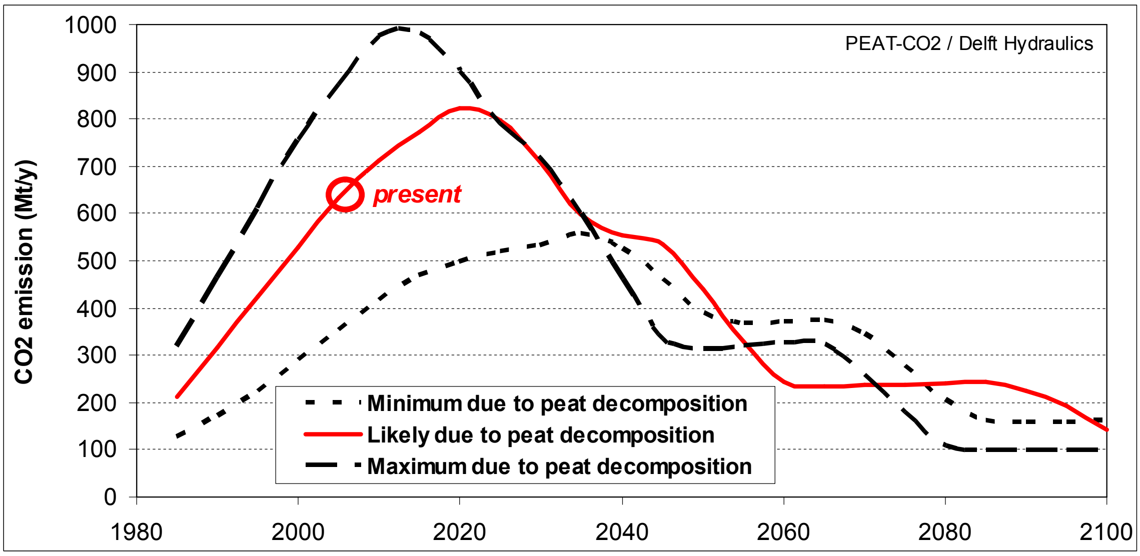

Figure 13 Historical, current and projected CO_2 emissions from peatlands, as a result of drainage (fires excluded). The increase in emissions is caused by progressive deforestation and drainage of peatlands. The decrease after 2020 ('likely' scenario) is caused by shallower peat deposits being depleted, which represent the largest peat extent (see Figure 3). The stepwise pattern of this decrease is explained by the discrete peat thickness data available (0.25m, 0.75m, 1.5m, 3m, 6m, 10m).

Note that peat extent and -thickness data for 1990 (Sumatra) and 2000 (Kalimantan) have been assumed at the starting year of the analysis, in 1985. Considering the uncertainty margin around these data, and the likely systematic underestimation of peat thicknesses, this does not introduce a large additional error in the analysis.

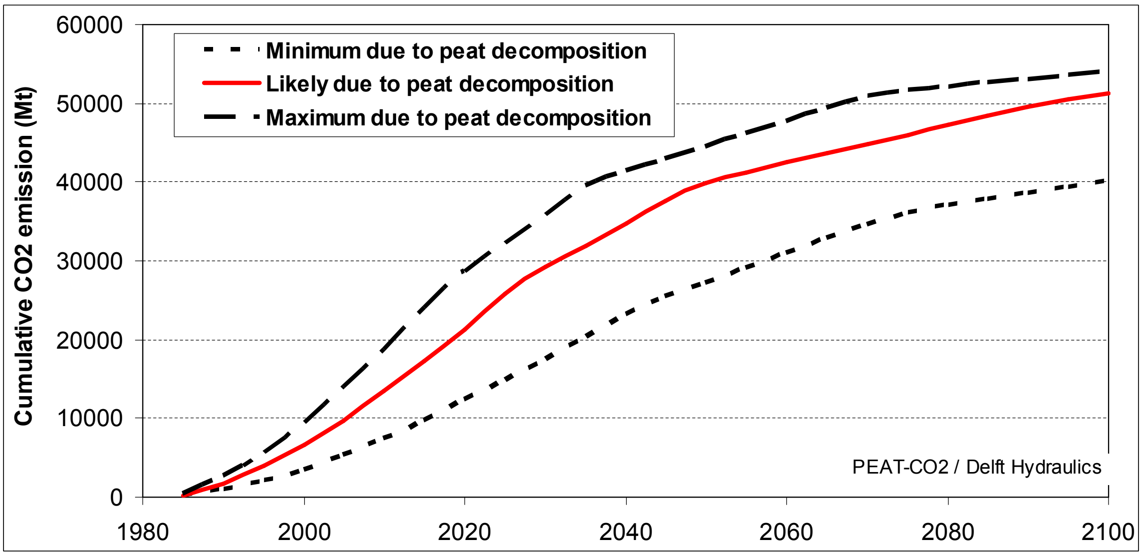

Figure 14 Cumulative CO_2 emissions from SE Asia. Note that total storage is at least 155,000 Mt CO_2 (42,000 Mt carbon). This means that A) CO_2 emission through drainage alone can continue for centuries, and B) even if fire emissions are included in the projections, i.e. not stopped in the near future, the resulting higher emissions will continue for many centuries.

3.4 CO_2 emissions from peatland fires

The PEAT-CO2 research focuses on the little known issue of emissions caused by peat decomposition in drained peatlands, not on the better-known issue of emissions caused by peat fires. However, a rapid assessment of emissions due to fire is included in this report for two reasons:

1. Fires, like decomposition, are the direct result of peatland deforestation and drainage (Figure 17). In common with CO_2 emissions from decomposition emissions caused by fires, which combust both above-ground vegetation and the surface peat, provide a powerful argument for conservation and rehabilitation (in remaining forest areas) and management improvements (in plantations and agricultural areas).
2. Studies are underway which will allow calculation of fire risk- and frequency as a function of water depth and land management, similar to the way we now calculate decomposition emissions. Inclusion of fire emissions is likely to be part of further refinements of the PEAT-CO2 calculations in 2007.

The assessment presented here is based on two main information elements:

1. A study of CO_2 emissions due to peat fires in Indonesia in 1997 (Page et al, NATURE, 2002) puts this figure between 810 and 2470 Million tonnes carbon loss (i.e. 3000 to 9000 Mt CO_2 emission) for that single event, or 15 to 40% of fossil fuel emissions in that year. This number is supported, amongst others, by the fact that 1997 has had the largest annual jump in global atmospheric CO_2 on record.
2. An annual fire hotspot count over 1997-2006 (Figure 15) for Borneo, using satellite data. This data is yet to be published and was kindly provided by Dr Florian Siegert of Remote Sensing Solutions. The data show that over 60,000 fires were counted in three out of 10 years: 1997, 1998 and 2002. The 2006 data in Figure 15 are incomplete (they include fire counts up until mid-October whilst fires continued for a further month) and are likely to be near those of the other major fire years. Publications by Siegert et al (NATURE, 2001) and Page et al (NATURE, 2002) confirm that the 1997 fires occurred mainly in degraded areas (peatland and non-peatland), associated with logging and development projects.

It should be noted that while there were major fire years in 1997, 1998, 2002 and 2006, when millions of hectares were burnt and regional haze problems became a political issue between Indonesia, Malaysia and Singapore, large peat areas are burnt every year and haze problems in areas of Sumatra and Kalimantan are now considered normal in the dry season.

The rapid assessment approach was to relate the 1997 hotspot count for Kalimantan (which is 90% of the Borneo count, Siegert pers. comm.) to the emission range provided by Page et al (NATURE, 2002), and then to apply it to other years proportional to the hotspot count. This results in the annual minimum and maximum emissions shown in Figure 16. These numbers result in a minimum average CO_2 emission (over 1997-2006) of 1418 Mt/y, and a maximum of 4324 Mt/y.

The rapid assessment method applied yields tentative results, and publications on more thorough analyses of CO_2 emissions from peatland fires in SE Asia are expected in the near future. For one thing, the annual hotspot count applies to both peatlands and non-peatlands. While the 1997 hotspot count is almost equal to that of 1998, fires in the latter year are known to have affected peatlands to a lesser extent than in the first year. Another point is that single fires in dry years affect greater areas, and burn away deeper layers of peat, than fires in wet years which are unlikely to affect peatlands to the same extent. This implies the hotspot count in peatlands is not fully proportional to CO_2 emissions from peatlands; a doubling of the number of fires more than doubles CO_2 emissions. Yet another point is that emissions from fires outside of Indonesia are not included, while Malaysia and Papua New Guinea are known to have peatland fires as well.

The net effect of these limitations of the rapid assessment method will be an overestimation of CO_2 emissions. We therefore consider the lower number more realistic than the higher number. We accept an annual CO_2 emission from peatlands fires in Indonesia of 1400 Mt/y as a tentative estimate; the emission from peatlands in other SE Asian countries is unknown.

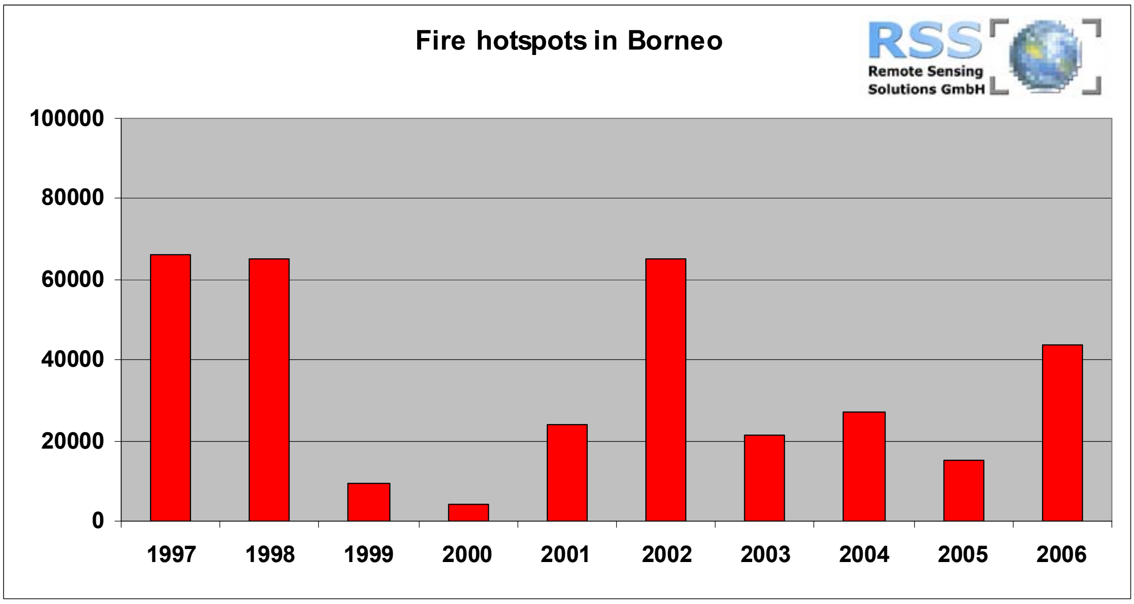

Figure 15 Fire hotspot data (number of fires counted, per year) for Borneo as detected by satellites(NOAA, ATSR and MODIS) from 1997 to 2006. These tentative data are yet to be published but were provided by Dr Florian Siegert (Remote sensing Solutions GmbH, Germany) to allow this study to derive a tentative estimate of annual CO_2 emissions from fires.

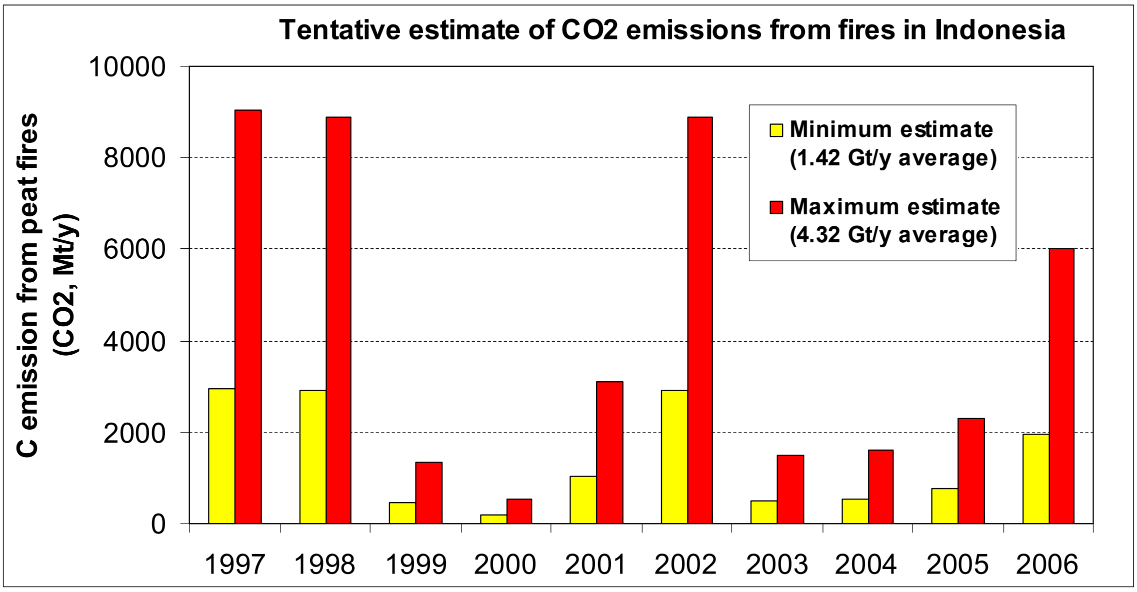

Figure 16 Tentative estimate of annual and average annual carbon emissions due to peatland fires, determined on the basis of hotspot counts for Borneo (see figure above) and the carbon emissions calculated by Page et al for 1997 (NATURE, 2002). Better estimates are being prepared for publication by Page, Siegert and others.

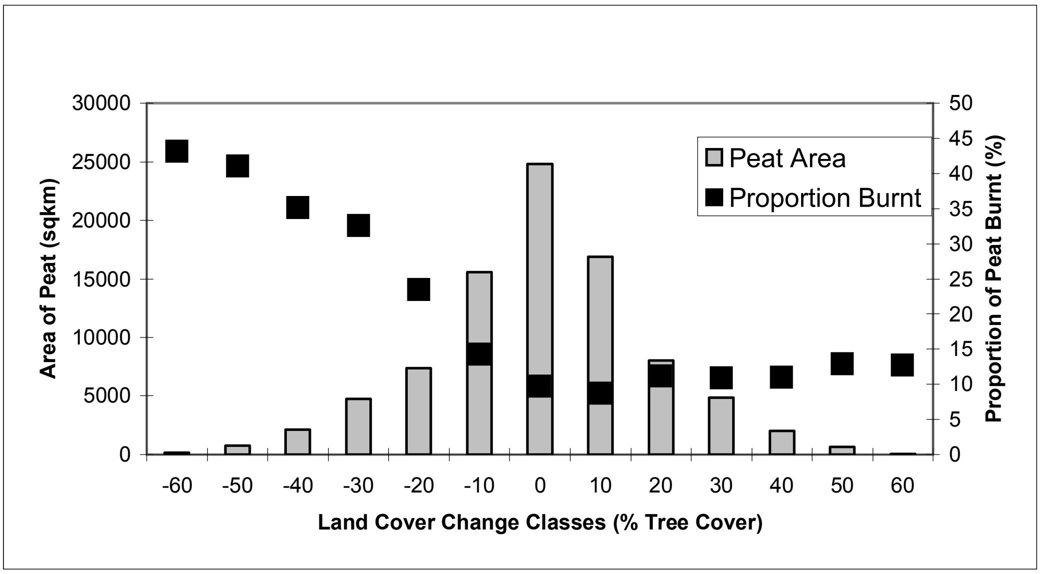

Figure 17 Relationship between Land Cover Change, Total Peat Area and Proportion of Peat Area Burnt for Kalimantan, 1997 to 2003.

This graph was provided by Allan Spessa, Ulrich Weber (Max Planck Institute for Biogeochemistry, Jena, Germany) and Florian Siegert (Remote Sensing Solutions GmbH), and is based on research that will be published separately in the near future. The graph clearly illustrates the close link between deforestation, land management and elevated peat burning. The proportion of peat burnt between 1997-2003 was several orders of magnitude higher in areas experiencing deforestation, that is, negative land cover change, than in other areas. In peatlands experiencing a net loss in land cover between 1997 and 2003, there is a very strong positive correlation between the magnitude of area burnt and the magnitude of land cover change ($R^2 = 0.96$, $N = 7$ classes including the no-change class).

4 Discussion of uncertainties

The current report is the result of an assessment using the latest available data. The subject matter is complex and not well-studied, as the importance of CO_2 emissions from SE Asian peatlands and the role of water management is only now starting to be widely recognized. Therefore, there are several uncertainties in the assessment.

The uncertainties will be discussed here briefly to A) indicate the level of confidence we have in specific results and B) identify areas where better data would allow reduced uncertainty, i.e. identify targets for follow-up research. The discussion shows that we have aimed to use conservative numbers and assumptions at every step of the analysis. As a result, we consider the chance CO_2 emissions are underestimated to be greater than the chance they are overestimated.

4.1 Uncertainty sources

4.1.1 Input data

Peat thickness. There are three main sources of uncertainty:

1. The thickness of the more remote and less well-mapped peatlands in Indonesia is not very well known. As peat thicknesses tend to be greatest in the central parts of these highly inaccessible and often vast (tens of kilometres across) peatlands, this is likely to result in an underestimation of peat thickness and therefore in an underestimate of long-term CO_2 emission.
2. Data on the thickness of peatlands in Malaysia and Papua New Guinea were not available at the time of this study. Conservative assumptions were made, which will likely result in an underestimate of long-term CO_2 emission.
3. Data on recent loss of peat in areas with limited peat thickness. Peat thickness data used are based on field surveys between 1990 and 2002. These data were then used as the starting point of the CO2 emission simulation, in 1985. As some areas were already drained during the field surveys, and therefore reduced in thickness, the peat thickness in 1985 is underestimated for these areas. This means that the simulated rate of depletion of shallow peat deposits is greater than the actual rate, i.e. simulated CO_2 emissions peak earlier and decline slightly faster than actual emissions.

It is concluded that the uncertainties in peat thickness all lead to an underestimate of CO_2 emissions, in the longer (1, 2) or shorter (3) term. The impact on long-term emission simulations is probably greater than on the short-term emission simulations.

Extent and distribution of peat lands. The data on peat extent available to the project can be improved especially for areas outside of Kalimantan and Sumatra, where FAO data from the Digital Soil Map of the World were used. However, comparison of these data for Kalimantan and Sumatra with the more recent and detailed Wetlands International data showed greater differences in distribution than in total extent.

Carbon content of SE Asian peat. Carbon content depends on A) bulk density of the peat material (i.e. percentage solid matter vs water) and B) carbon content of the solid matter, which both vary with source material and degree of decomposition. Carbon contents between 90 kgC/m^3 and 45 kgC/m^3 have been published for various peat deposits in SE Asia. The relation between subsidence rate and CO_2 emission applied in this assessment (Wösten and Ritzema, 2002) assumes a carbon content of 60 kg/m^3 which is fairly conservative and does not introduce a great uncertainty to the result.

Carbon store. The carbon store in SE Asian peatlands is not input data but a function of A) peat thickness, B) peatland extent and C) peat carbon content. As described above, peat thickness is considered to have the greatest uncertainty and is likely to be underestimated. This means the total carbon store may also be underestimated. This will have an impact especially on the CO_2 emission projections in the long term, less in the short term.

Land use / land cover. The GLC 2000 global land cover classification was used to determine land use for SE Asia in the year 2000. The decision rule that 'mosaic cropland + shrubland' on peatland is always accompanied by drainage introduces some uncertainty especially in the case of Papua (in Indonesia). Here, areas are classified as 'mosaic cropland + shrubland' that are known to be a savannah-like landscape created by traditional land management techniques requiring regular burning of the Melaleuca and herbaceous peat swamp vegetation (Silvius & Taufik, 1990). These areas are generally non-drained, agriculture often takes place on elevated islands of dug up mud (from the submerged swamp soil), which probably causes less peat oxidation. It is therefore likely that the emissions (per unit area) from these areas are relatively minor compared to the emissions in Sumatra and Kalimantan. This may have lead to an overestimate of CO_2 emissions from SE Asian peatlands, with a maximum of 16% in the unlikely case that emissions from Papua would actually be negligible.

Percentage of peatland drained. Drainage intensity was estimated as a function of land use / land cover (Table 5), in consultation with the experts involved in the study. The estimate is considered conservative but does introduce some uncertainty. Additional uncertainty is introduced by the fact that an unknown but probably significant drained peatland area is not included in the analysis: forested areas affected by legal and illegal logging (canals are often used in log transport), plantation drainage (which may bring down peatland water levels over several kilometres in the longer term) and fires (which create depressions in the peat surface). In the early 1990s already, over 90% of peat swamp forests in Sumatra were affected by human interventions such as forestry, agriculture and related drainage (Silvius & Giesen, 1992); the present extent and degree of these impacts in remaining forests in SE Asia is very significant but not well-documented. The overall effect of this uncertainty is probably an underestimate of the overall drained peatland area.

Drainage depth. Drainage depth was estimated in consultation with the experts involved in the study. Estimates are considered conservative especially for heavily drained areas (plantations and abandoned plantations like the ex-Mega Rice Project), where drainage depths well over 1 metres are often observed while a 'likely' drainage depth of 0.95m was assumed in the assessment (Table 5). Similarly, a drainage depth approaching 1 metre may be more realistic in many small-scale agricultural areas than the depth of 0.6m used as 'likely' value in the analysis. The overall effect of uncertainties is therefore probably an underestimate of the overall drainage depth.

Percentage of oil palm plantations on peat lands. For precise assessment of the CO_2 emissions caused by palm oil production on peatlands alone, accurate data on the present extent of oil palm plantations on peatlands are needed that are now lacking. Currently our estimate is that some 25% of palm oil plantations is on peatlands, following from the fact that 27% of oil palm plantation concessions (i.e. existing and planned plantations) are on peatlands. This uncertainty does not affect the assessment of CO_2 emissions from peatlands, but does affect our knowledge of how much of this emission is caused by palm oil production.

4.1.2 Emission relations

Relation between drainage depth and CO_2 emissions. There is significant uncertainty in the CO_2 emission resulting from a specific drainage depth. Few long-term studies of subsidence rates in drained peatlands in SE Asia have been published. Short-term studies of CO_2 emissions are difficult to interpret because A) CO_2 emissions from root respiration must be separated from emissions caused by decomposition, B) short-term effects (shortly after drainage) must be separated from long-term effects, and C) water table and soil moisture regime are often insufficiently monitored. Because of this potential uncertainty, a thorough literature review was compiled (see Table 6). The relation used in the assessment, derived on the basis of this review, is considered conservative.

CH_4 emission. The only form of carbon emission to the atmosphere considered in this assessment is CO_2 (carbon dioxide) emission. CH_4 (methane) emissions from drained peatlands are considered by most experts to be limited in comparison, but may still be significant because CH_4 is a far stronger greenhouse gas (23 times stronger in 'carbon dioxide equivalents'). CH_4 emissions in peatlands may originate especially where peat areas are flooded for prolonged periods after fires or after subsidence due to drainage, and reduced conditions are created in the peat soil. The uncertainty in this emission, is considered low, as research so far indicates that CH_4 emissions from tropical peatlands are negligible (Jauhiainen et al, 2005), so it has been excluded from the assessment. This may result in an underestimate of the total emission of greenhouse gases (in carbon dioxide equivalents) from drained and burnt peatlands.

Peat fires

The CO_2 emission due to peatland fires is highly uncertain. Separate publications on this issue are expected in the near future. Ideally, fire risk is quantified as a function of land use (drainage depth and land management), so future CO_2 emissions caused by fires can be simulated as was done for CO_2 emissions caused by oxidation. Until that is possible, emissions caused by fires remain the relatively largest uncertainty in emission projections. As explained in the text, the current assumption of 1400 Mt/y of CO_2 emissions from fires is at the lower end of the estimated range (1400 to 4300 Mt/y). The likelihood of this number being an underestimate is therefore considered greater than of it being an overestimate.

4.1.3 Trends and projections

Deforestation trend assessment. The main trend assessment performed was of deforestation between 1985 and 2000, with a verification for 2000-2005. Overall uncertainty in this assessment is fairly limited as well-researched sources were used. There is a greater likelihood that forest area in 2000 is overestimated than underestimated, due to inclusion in the 'forest' area of severely degraded forests and of timber plantations. The rate of deforestation assumed in the assessment is therefore considered conservative.

Drainage trend assessment. Drainage trend was established as a function of derived trends in development of cropland and 'cropland/shrubland mosaics'. These derived trends are highly conservative, e.g. the area of large-scale croplands can not exceed 21% of the peatland area even if all peatland is deforested, while the concession areas for palm oil and timber plantations alone already cover 23% of the peatlands in Indonesia.

Land use projections. As projections are a simple continuation of past trends, there are two uncertainties: those in the past trends and those in continuation of these trends into the future. The uncertainty in the latter is very significant, of course. The projections may turn out to be too pessimistic if SE Asian countries, supported by the international community, decide to drastically improve peatland conservation and management strategies. If such improvements do not materialize however, the projections may be too optimistic as the remaining peatland resources (forests, but also converted peatlands still suitable for agriculture) dwindle while demands (for timber and for agricultural land) increase.

4.2 Assessment of overall uncertainty

From the discussion of uncertainties presented above it is clear that A) there are significant uncertainties in most data and parameters used, and B) the assessment has consistently aimed to be conservative. Therefore, the resulting range in emissions (355 to 874 in 2006, with a most likely value of 632 Mt/y) is also considered conservative. This range accounts for uncertainties in drainage intensity and drainage depth. Uncertainties that are not included are those in peat thickness, carbon content of peat, relation between drainage depth and CO_2 emission, CH_4 emission and trends and projections in land use, especially in drainage. There is no obvious way to quantify the effect of these uncertainties, but it should be noted that most of them are higher to the upside than to the downside, i.e. emissions are more likely to be underestimated than to be overestimated.

An important point to note regarding these uncertainties is that most of them affect annual release of carbon to the atmosphere over the coming 10 to 50 years. Climate scientists are often interested in emissions in the long term (100 years or longer) and the precise annual emission in the short term is less relevant from that perspective. Halving the emission rate through marginal improvements in for instance fire fighting methods, but without fundamental changes in forest conservation and water management practices, would simply mean it takes twice as long to increase the global atmospheric CO_2 emission by the same amount. The implication is that most uncertainties discussed above may not be very important from a climate change perspective: more important is the fact that it can now be proved that most carbon stored in SE Asian peatlands is likely to be released to the atmosphere in the short or long term if current developments and practices are allowed to continue.

4.3 Proposed research activities to reduce uncertainties

A number of actions can be identified that will significantly reduce the uncertainty in the assessment of CO_2 emissions in the short term and the longer term. In 2007, it may be possible to improve the assessment using data that are expected to become available in the coming months:

1. Use of GLOBCOVER data for land use / land cover assessment. These data will apply to 2005 (data for 2000 were used in the current assessment), will have higher resolution (300m vs the 1000m used in the current assessment) and is expected to have higher accuracy.
2. Use of improved data on the present and planned distribution of oil palm and timber plantations and other intensively drained areas in peatlands.
3. Linked to the availability of more detailed and accurate land cover data and plantation data, is the option to develop land use scenarios for individual peatlands, rather than a single projection for all of SE Asia. This will also provide a basis for improved forest conservation and water management plans for these individual areas.
4. Use of improved data on peat extent and peat depth outside of Sumatra and Kalimantan. Such data are now being finalized by Wetlands International for Papua. Similar data are understood to be available in various databases for Malaysia (especially Sarawak) as well.
5. Inclusion of lateral processes in the peatland subsidence and emission calculations. These impacts do not stop at the boundary of a drained area, but affect a progressively larger peripheral zone. The width of that zone depends on drainage depth and peat characteristics (hydraulic conductivity, thickness, slope); it may extend for kilometres in years or decades. Inclusion of lateral processes will yield insight in the area affected by a drainage system.
6. Feedback effects from climate change. It is understood that most climate change models predict that the SE Asian peatland region, notably southern regions in Borneo and Sumatra, will become dryer in the future (Dr Pep Canadell, Director of Global Carbon Project, pers. comm.). This means that the need for improved conservation and water management will be even greater. Climate change projections can be used to quantify this effect.

Parallel to this, but possibly only yielding major uncertainty reductions in 2 years or more, the following activities are proposed:

7. Development of a physically-based relation between drainage depth, subsidence rate and CO_2 emission. This relation will likely be non-linear and may take into account water depth regime instead of average water depth. Separate relations may need to be defined in different land use types, to account for the effects of vegetation cover and land management (mechanized, fertilized etc).
8. Development of a stochastic relation (supported by physical considerations) between fire risk and land and water management practice, allowing prediction of fire frequency under different management strategies.

5 Conclusions and recommendations

The total amount of carbon in peatlands in SE Asia is at least 42,000 Megatonnes (depending on assumptions of peat thickness and carbon content), equalling at least 155,000 Megatonnes in potential CO_2 emissions. Present likely CO_2 emissions (fires excluded) from drained peatlands are calculated to be between 355 and 874 Mt/y, with a most likely value of 632 Mt/y. If current rates and practices of peatland development and degradation continue, this may increase to 823 Mt/y (most likely value) in 10 to 30 years, followed by a steady decline over centuries when increasingly thicker peat deposits become depleted.

Current emissions from Indonesia alone are 516 Mt/y. To put this in perspective, this equals:

- 82% of peatland emissions in SE Asia (fires excluded).
- 58% of global peatland emissions (Figure 18; fires excluded).
- Almost 2 times the emissions from fossil fuel burning in Indonesia.

If emissions from peatland fires (which are also caused by deforestation and drainage) are included, the total CO_2 emission number is significantly higher. Over 1997-2006, CO_2 emissions from peatland fires in Indonesia were several times those due to peat decomposition in drained peatland areas: 1400 Mt/y to possibly as much as 4300 Mt/y. The lower (and more likely) figure, added to current likely emissions from peat decomposition, yields a total CO_2 emission figure for SE Asian peatlands of 2000 Mt/y (over 90% of which are from Indonesia), equivalent to almost 8% of global emissions from fossil fuel burning. This is probably the most concentrated (produced on only 0.2% of the global land area) land-use related CO_2 emission in the world. If emissions from peatland drainage and degradation (including fires) are included, Indonesia takes third place in global CO_2 emissions, behind the USA and China. Without peatland emissions, Indonesia takes 21st place.

Interestingly, the annual CO_2 emission of 2000 Mt/y found for 2005 is supported by an independent study: Wetlands International has estimated an average annual emission of 1480 Mt/y between 1990 and 2002, based on mapping of lost peat areas and measurement of reductions in peat thickness in remaining peatlands. They found an area of 3.7 million hectares of historically mapped peatland to be fully lost by 2002, i.e. all peat was removed and the soil should now be classified as 'mineral' (Wetlands International 2003, 2004).

It should be noted that, while peat fire emissions currently exceed those from slower peat decomposition, this does not mean that the problem can be solved by fire fighting:

- First of all, peatland fires are promoted by deforestation and by forest degradation and peat drying linked to peatland drainage, and can be stopped in the longer term only if these root causes are dealt with.
- Secondly, only stopping the fires but not the drainage merely means it will take a longer time for the carbon resources to be released to the atmosphere. Climate scientists look at total emissions over long time intervals, e.g. 100 years, and may consider the timing of peatland emissions (with or without fires) less relevant.

It is concluded that, while fire fighting and emergency measures may be helpful in the short term, a fundamental change in the management of peatlands in SE Asia, especially Indonesia, is required if the carbon is to remain stored in peatlands. The most effective measure to achieve this is conservation of remaining peatland forests, alongside rehabilitation of degraded peatlands and improved management of plantations and agricultural areas. In all cases – conservation, rehabilitation and plantation management – the natural water table regime should be restored (or approached as much as possible) through improved water management, i.e. through less severe or no drainage.

Current developments give little reason for optimism: while deforestation rates on non-peatlands in SE Asia have decreased somewhat (at least in part due to depletion of forest resources), those in peatlands have been stable (on average) for up to 20 years. Current (2000-2005) average deforestation rate is 1.5%/y; lower values apply in Papua (and probably Papua New Guinea), higher values apply elsewhere. In 2005, 25% of all deforestation in SE Asia was on peatlands. Apart from logging for wood production, an important driver behind peatland deforestation is development of palm oil and timber plantations, which require intensive drainage and cause the highest CO_2 emissions of all possible land uses.

A particular point regarding CO2 emissions from SE Asia peatlands, which requires attention from the international community, is that of the relation between palm oil production and peatland drainage. A large fraction (27%) of palm oil concessions (i.e. existing and planned plantations) in Indonesia is on peatlands; a similar percentage is expected to apply in Malaysia. These plantations are expanding at a rapid rate, driven in part by the increasing demand for palm oil as a biofuel on Western markets. Production of 1 tonne of palm oil causes a CO_2 emission between 10 and 30 tonnes through peat oxidation (assuming production of 3 to 6 tonnes of palm oil per hectare, under fully drained conditions, and excluding fire emissions). The demand for biofuel, aiming to reduce global CO_2 emissions, may thus be causing an increase in global CO_2 emissions.

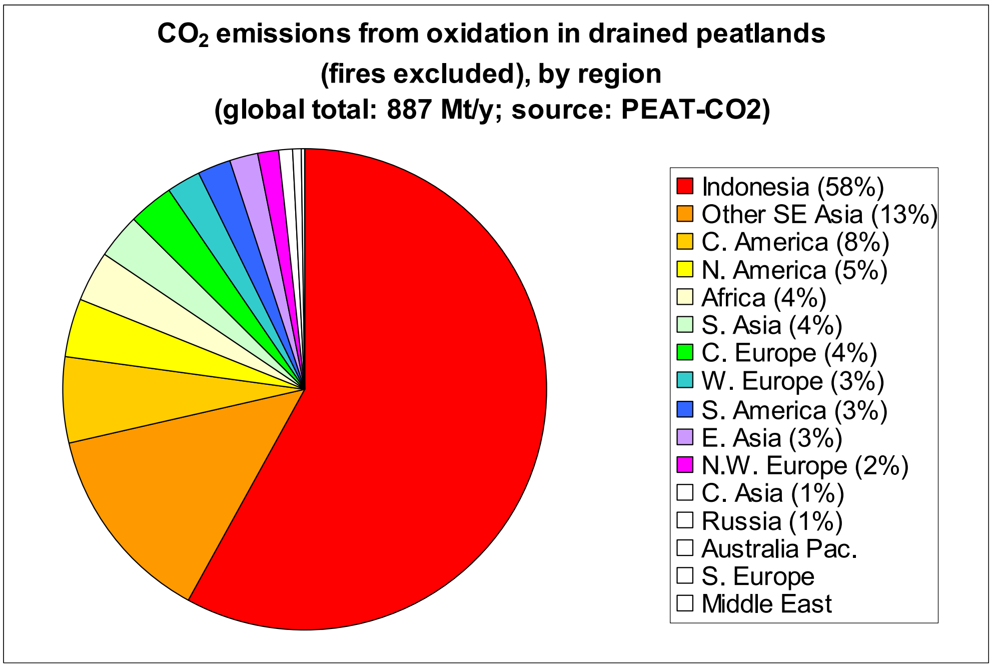

Figure 18 CO_2 emissions from peatlands in Indonesia and the rest of SE Asia as compared to emissions from other peatland regions in the World. This is a tentative calculation for areas outside of SE Asia, using FAO soil data and GLC 2000 land cover data. Note that emissions owing to fire are not included; nor are emissions from peat burning for energy and due to drainage other than for agriculture.

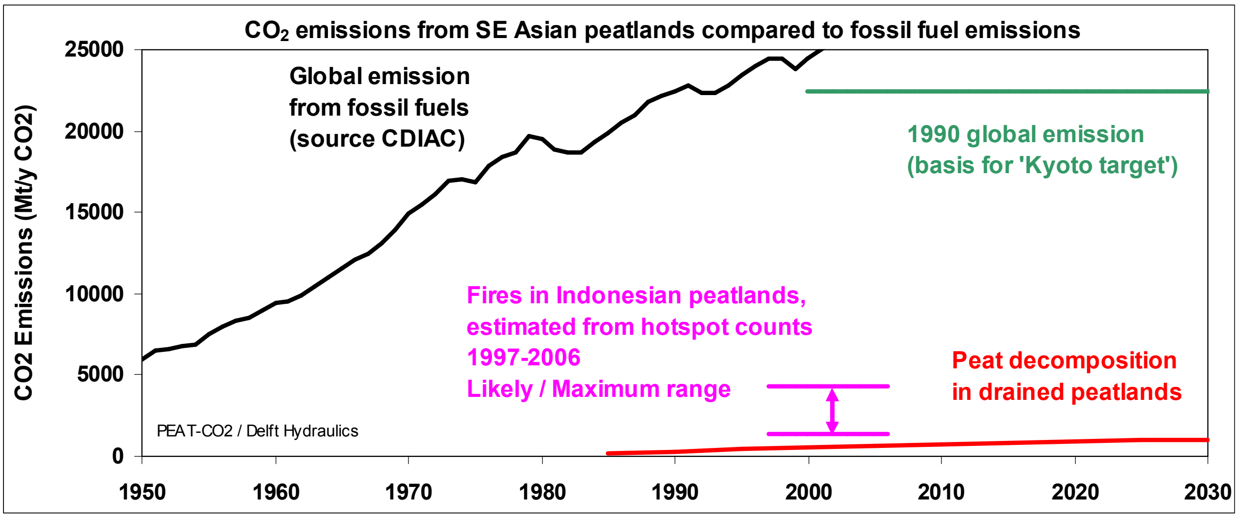

Figure 19 Comparison of emissions from drained and burning peatlands in SE Asia with global emissions from fossil fuel burning.

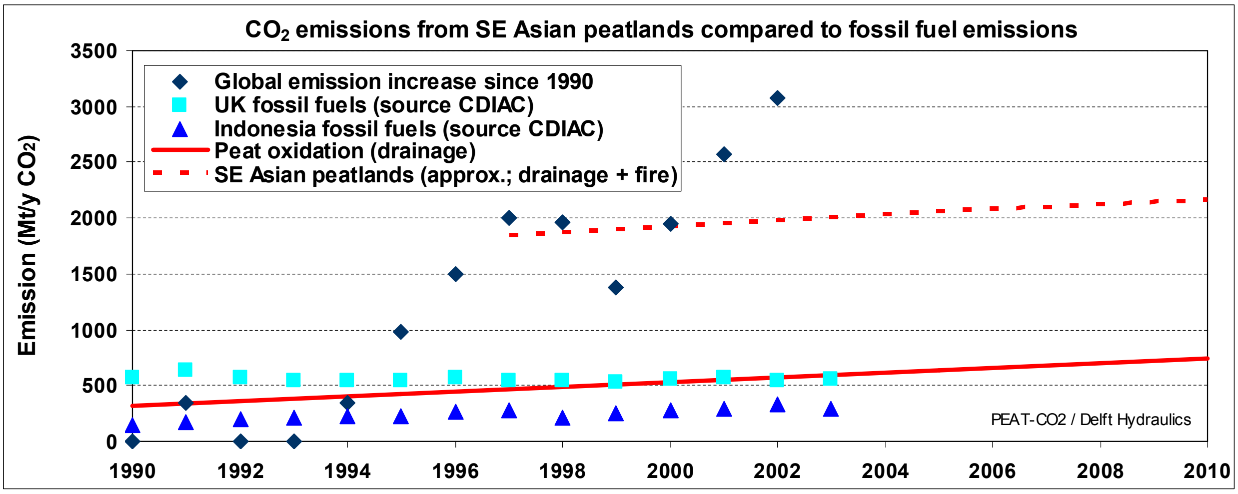

Figure 20 Comparison of emissions from drained and burning peatlands in SE Asia with global emission increases since 1990 (the benchmark year for the Kyoto Protocol) and with national fossil fuel emissions in Indonesia (the source of 90% of peatland emissions) and the UK (as an example of emissions from a large industrialized nation).

5.1 Recommendations for improved peatland carbon conservation

To reduce CO_2 emissions from SE Asian peatlands, a drastic change in land and water conservation and management practices is required. The measures needed to reduce CO_2 emissions would also reduce other negative effects of current peatland management practices:

- Haze problems caused by peat fires, which affect public health and economy (impact on natural resource base, tourism and transport sectors) in the entire region;
- Productivity loss in plantations on deep peat, which often become undrainable within decades because of peat subsidence;
- Loss of natural timber production in the longer term owing to degradation of remaining forests;
- Loss of biodiversity;
- Flooding problems downstream of drained and degraded peatlands;
- Salt water intrusion and development of acid sulphate soils in coastal areas.

Policy

Emissions and other negative effects of unsustainable peatland management can only be reduced if a land development policy based on the following three principles is adopted:

1. Forest **conservation** and drainage avoidance in remaining peat swamp forests.
2. Where possible **restoration** of degraded peatland hydrological systems and peat swamp forests or other sustainable vegetation cover.
3. **Improved water management** in peatland plantations, embedded in water management master plans for peatland areas.

In addition, peatland development planning should be based on the following three approaches:

- **Precautionary approach.** In planning of land-use in peatlands, it is advisable to use the precautionary approach. Large scale developments in peatlands should be pursued only after considerable research and after successful completion of pilot projects.
- **Hydrological system approach**. Land-use planning in peatlands should follow the ecosystem approach, taking special account of the hydrological vulnerability of peat domes and the ecological relationships with the surrounding habitats and land-uses. Particular regard should be given to the place of the area within the water catchments/ water shed, and the potential impacts of and on upstream and down stream habitats and land-uses (including potential land-uses). In peat swamp forests it may be necessary to consider multi-river basin complexes, as multiple watersheds may be dependent on shared peat domes, and impacts on one river basin may affect the shared hydrological basis.
- **Integrated approach**. Wise management of peatland ecosystems requires a change of approach from single sector priorities to integrated planning strategies, involving all stakeholders to ensure that consideration is given to potential impacts on the ecosystem as a whole. Land-use planning in peatlands should involve all relevant sectors and major stakeholder groups, including local people, from the outset of development planning. A precondition for successful integrated planning is the (enhancement of) awareness of the various groups regarding peatland ecology and hydrology, and the full scale of values that peatlands may have:
    a. The use of a peatland for a specific purpose may have considerable side effects and all other functions must be taken into account in the full assessment of the suitability of a particular use.

b. With respect to side effects, a use could be considered permissible when:
   - negative side effects will not occur, or
   - the resources and services affected will remain sufficiently abundant, or
   - the resources and services affected can be readily substituted, or
   - the impact is easily reversible, or
   - an integrated cost benefit analysis involving thorough consideration of all aspects of the proposed use yield a positive advise.

Water management measures

In practice, implementation of a CO_2-reduction policy will require a strategy that includes the following measures:

- **Conservation of peat swamp forest.** In a natural system, peat domes gradually release water into adjoining depressional peat swamps, which slowly release it to streams and rivers. High water tables are thus maintained during the dry season in peat domes, peat swamps and river corridors. The simplest and most effective measure to prevent a further increase in fires and CO_2 emissions is thus by conservation of remaining peats swamp forests and rehabilitation of degraded peatswamp forests.
- **Maintenance of water stores in rehabilitated peat swamps.** The peatland hydrological system is degraded through any drainage, even limited drainage for (illegal or legal) log transport. The result is A) dry peat forest soils and increased fire risk, B) enhanced peak flows in the wet season contributing to downstream flooding, C) reduced low flows in the dry season, causing lower water tables ant enhanced fire risk in downstream areas. For example, it is thought that drainage in the Air Hitam Laut watershed has contributed to extensive fires in the downstream Berbak National Park (Wösten et al, 2006). Restoration of water storage in swamps, through water management measures aiming to elevate water levels over large areas and restoration of the natural peatland hydrological system (which will take many years), would contribute to reduced fire risk and CO_2 emissions both locally and in downstream areas. This measure is best linked to rehabilitation of peat swamp forest vegetation, which requires careful water level control to allow forest regeneration.
- **Implementation of operational water management systems in plantations.** Current water management systems in peatlands are mostly unsuitable for peatland conditions: the main objective now is generally to prevent flooding in the wet season, whereas an equally important target should be to prevent falling water levels and increased subsidence and fire risk in the dry season. Operational water management systems are needed that can be adjusted to meet different targets throughout the year and thus optimize productivity while minimizing fire risk and CO_2 emissions.
- **Water management master planning.** Water levels in peatlands can be optimized, and fire risk and CO_2 emissions minimized, if water management is planned and co-ordinated for entire peat bodies (i.e. entire hydrological units). When using this integrated landscape-based approach the current distinction made between of areas deeper or shallower than 3 meters becomes should be revised. This distinction, first developed in the Indonesian Presidential Decree 32/1990 does not provide guidance for sustainable peatland management. The master planning process requires involvement of all major stakeholder groups: Government, communities, concession holders and NGOs.
- **Land and water management capacity building.** Management requirements in peatlands are very different from those in other areas, and require an understanding of the hydrological system that is usually lacking in present peatland water management in SE Asia. Also, it is sometimes thought that fire fighting is the solution to the recurrent peatland fires; this is true only to a small extent because A) peatland fires are nearly impossible to extinguish once they are established over large areas and B) the root cause of fires is the drying of peat through drainage. Furthermore,

peatland CO_2 emissions are not only caused by fires but also by slow decomposition. Development of water management capacity in peatland areas is crucial for reduction of CO_2 emission from those areas.

Other measures:

- **International Assistance:** A strategy for improved peatland conservation and management would benefit from official recognition of the SE Asian peatlands as globally important carbon stores that require carbon conservation management if CO_2 emissions are not to continue at current levels or even increase. On this basis, alongside the arguments of sustainable development, haze reduction and biodiversity conservation, international funding could be made available for conservation of peatland forest, rehabilitation of degraded areas, and improvement of water management in agricultural/plantation areas. This should involve multi donor cooperation, long-term commitments from the global community, development of social and financial security for local stakeholders, good governance, and development of alternative financial mechanisms enabling rapid capacity building and implementation of conservation, rehabilitation and sustainable development programmes.
- **Poverty reduction.** Many of the problems in SE Asian peatlands impact negatively on the local communities and their development opportunities. Poverty rates in Indonesian peatlands are up to four times higher than in other areas in Indonesia and respiratory and related diseases caused by peat smog are a significant public health issue in the degraded peatland areas. Without alternative sustainable development options local communities will increasingly be forced to over-exploit the remaining natural resources in peatlands, further worsening the problems of deforestation, overdrainage and fires and thereby increasing CO2 emissions. It is therefore crucial that development, rehabilitation and conservation measures in peatlands will have a pro-poor approach. This should incorporate strategies to:
  - develop alternative jobs and income,
  - develop alternative – sustainable - ways of using peatlands for agriculture, fisheries, forestry and plantations that require no drainage,
  - monetarize the international value of peatlands (e.g. carbon and biodiversity values).
- **Monitoring** of land and water management. CO_2 emissions from peatlands should be recognized as a major contribution to greenhouse gas emissions that should be curbed. The international community is likely to require monitoring programmes for forest conservation and water management in SE Asian peatlands.

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