Environmental Protection Encouragement Agency EPEA EPEA Internationale Umweltforschung GmbH

Food for Fuel?

A Scientific Assessment of Environmental and Social Impacts of First-Generation Biofuels

Report without annex

EPEA Internationale Umweltforschung GmbH

Hamburg, Mai 2007

The complete report contains an annex with further background information used for the generation of statements presented in the present document.

The full report can be ordered in English or in German at epea@epea.com

Abbreviations

bn :	Billion
DM	Dry matter
EEA:	European Environmental Agency, Copenhagen
EJ:	Exajoule = 1 x 10^{18} Joule
FAO:	Food and Agriculture Organization of the United Nations, Rom
GJ:	Gigajoule = 1 bn Joule
Gt:	Gigaton = 1 bn tons
MJ:	Megajoule = 1 Mn Joule
Mn :	Million
OECD:	Organisation for Economic Co-operation and Development, Paris
PJ:	Petajoule = 1 x 10^{15} Joule
tOE:	ton of Oil energy equivalent
UNDP:	United Nations Development Programme, New York
UNEP:	United Nations Environmental Programme, Nairobi
WHO:	World Health Organization, Geneva

Introduction

On February 20. 2007, the European Council of Environmental Ministers adopted the goal to reduce the overall carbon dioxide emissions of the European Union for 20% until 2020, compared with emissions of 1990 [1]. The decision contains further an extension of the currently mandatory goal for a share of 5.75% biofuels in the transportation sector in 2010. Now the goal for the biofuel share is fixed at 10% by the year 2020. With an increasing share of biofuels in transportation, one expects a contribution to the reduction of greenhouse gas emissions. On January 9. 2007, the EU commission informed the European Council and the European Parliament that problems are however getting visible making reaching the target of 5.75% of fuel substitution in 2010 unlikely [2, 3].

"First-generation biofuels" include biodiesel and ethanol that are produced using food crops as feedstocks. Biodiesel is made via transesterification of vegetable oils, especially from palm and rapeseed. Ethanol is made by fermenting sugar from sugar beets and sugar cane or starch contained in maize or wheat. These First-generation biofuels deserve closer attention with regard to their impacts on greenhouse gas emissions, food security, soil demand, soil fertility and biodiversity. First-generation biofuels are distinguished from second-generation biofuels, which include ethanol derived from cellulose and synthetic fuels obtained from biomass after gasification of the whole plant. These processes are still a matter for development.

There is sound scientific evidence, which supports the view that First-generation biofuels will create much more problems than they will solve, including:

- Deforestation
- Increase in greenhouse gas emissions
- Requirements for land that does not exist to achieve positive environmental effects
- Enhanced food insecurity
- Creation of more poverty
- Increased soil degradation
- Decreased biodiversity
- Accelerated depletion of natural resources
- When they are effective carbon dioxide abatement options, they are not cost efficient.

Finally, this report proposes less damaging alternatives which have a better efficiency regarding greenhouse gas emissions at lower costs.

First-generation Biofuels can induce tremendous Greenhouse Gas Emissions

In August 2006, the first shipment of 60,000 tonnes biodiesel derived from palm oil left Malaysia for Germany [4]. This event has been largely overlooked but deserves closer attention. Malaysia – together with Indonesia - is the main palm oil producer worldwide [5] and likely to perform such shipments more often in the future if EU targets are to be reached. Assuming a practical yield of not more than 5 tonnes of palm oil per hectare, at least 12,000 ha of agricultural land was necessary for the production of this first shipment's biodiesel [6; 7]. This amount of fuel saved 53,000 tonnes of conventional diesel and the emission of 168,000 tonnes of the greenhouse gas carbon dioxide. The EU Commision's progress report, however, has overlooked the fact that these saved emissions come at the cost of deforestation in Southeast Asia and even higher greenhouse gas emissions. Both Malaysia and Indonesia grow palm trees on land formerly occupied by rainforests. These rainforests stored carbon aboveground in huge amounts at roughly 235 tonnes per hectare prior to deforestation [8]. They are released as carbon dioxide to the air immediately due to incineration or after a delay or years of few decades resulting from a transient use as furniture or construction material prior to incineration. A palm tree plantation area of 12,000 hectares was required for the production of the first shipment of Malaysian biodiesel to Germany and has therefore led to the initial emission of at least 10 million tonnes of carbon dioxide. 20% of these emissions have been fixed again as palm trees (48 tonnes of carbon per hectare [8]). In other words, 8 million tonnes of carbon dioxide have been emitted prior to refixation of 168,000 tonnes in the form of 60,000 tonnes palm oil and to saving of 53,000 tonnes of conventional diesel per year (Calorific values of biodiesel and conventional diesel used for calculation are 37.8 and 42.8 MJ/kg respectively [9]). It would require palm oil production over the next 59 years on this land to compensate for the original huge emission of carbon dioxide that resulted from deforestation with saved emissions of conventional mineral oil derived based. Further, if the energy demand for palm oil production, harvesting and transformation to biodiesel is considered, this figures climbs up to 74 years.

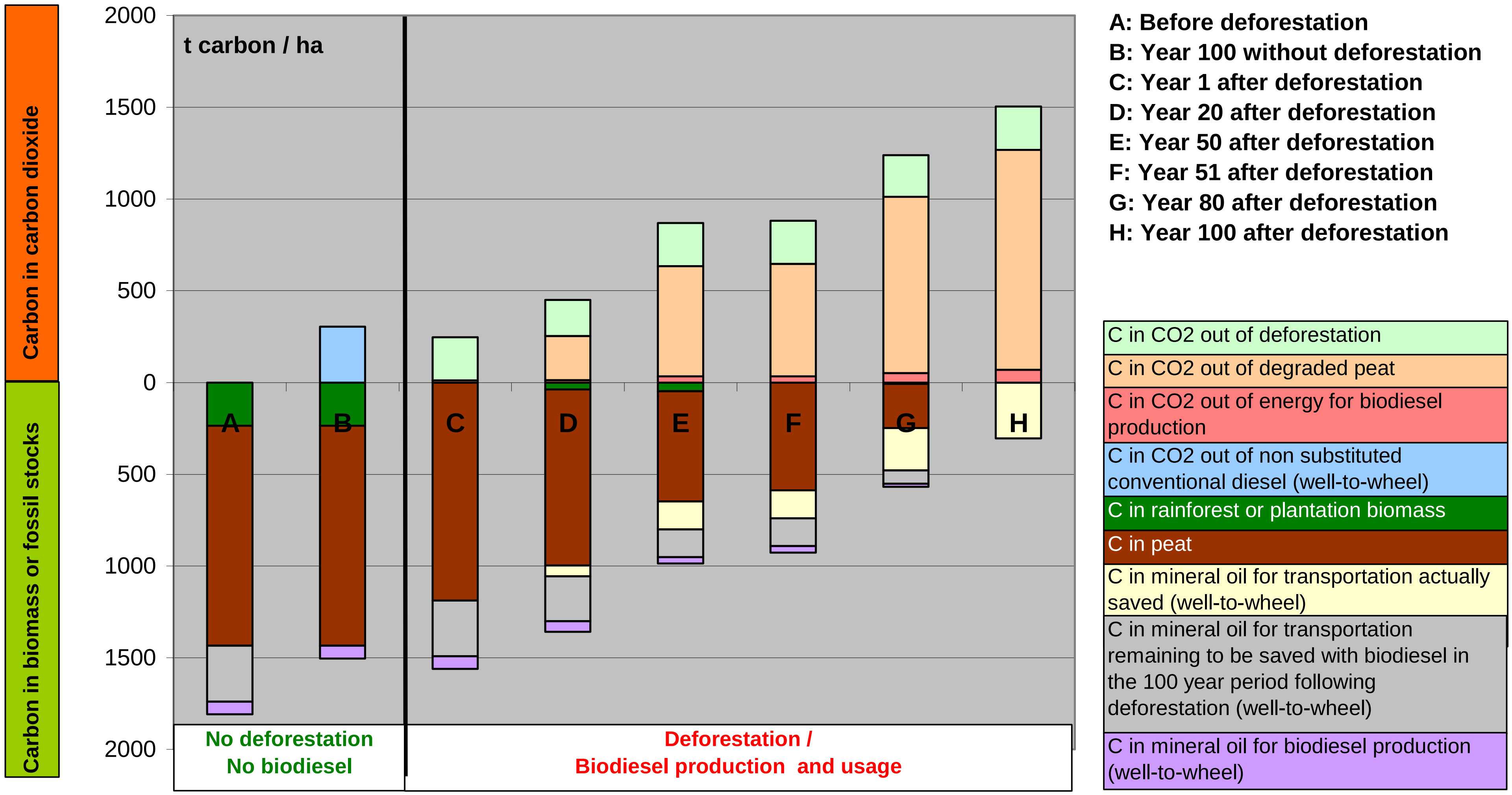
But that’s not all.

In Southeast Asia (Indonesia, Malaysia, Brunei and Papua New guinea), 27.1 Mn hectares or 10% of the total area are peatland, most of which being located in Indonesia. Peatland is a huge stock for carbon. The conversion of rainforest to agriculture with measures like incineration and drainage leads to conversion of stored carbon to carbon dioxide and its release into the atmosphere, too. Amounts in question are even larger than were already released with deforestation [10]. Rather conservative estimates point out to about 1,200 tonnes of carbon per hectare in the underground of peatland. After deforestation, they get accessible to conversion to carbon dioxide at a rate of 10-15 tonnes per year over about a century or even within few month or years due to peat fires [8, 11].

Taken together, all these contributions to the generation of carbon dioxide will by far not be able to be compensated over time: After a century of palm cultivation and palm oil biodiesel production and use, 5,510 t of carbon dioxide will have been emitted per hectare: 860 t out of deforestation, 4,400 out of peat degradation and 250 tonnes as the result of palm oil production, harvesting and transformation to biodiesel. If this reference hectare of forest had remained unchanged and peat was still in the underground and fuel used for transportation had remained conventional diesel, only 1,110 tonnes of carbon dioxide (20.1%) would have been emitted. Despite appearances, biodiesel is not derived from renewable resources as Figure 1 shows.

Further greenhouse gas emission like laughing gas are also set free in the course of biodegradation of biomass resulting from the change in land use. These gases have a higher relative potential than carbon dioxide to contribute to the greenhouse effect. Taking them into consideration would therefore further worsen the picture.

Figure 1: Evolution of the state of carbon related to 1 ha of rainforest on peatland used for palm oil biodiesel production



The United Nations Environmental Programme has published figures in the 90's attributing 20% of greenhouse gas emissions worldwide to change in land use and non-renewal of biomass [12]. Other more recent figures regard changes in land use as being responsible for more than 30% of greenhouse gas emissions [13].

The case of the first shipment from Malaysia shows how it can occur. Figures from the Food and Agriculture Organization (FAO) and the Organisation for Economic Cooperation and Development (OECD) predict nearly a doubling of palm oil production by 2030. This level of production will require the deforestation of 4 to 6 million additional hectares [8; 14], most of which will probably occur in Southeast Asia and for a part on peatland.

Palms are the most efficient oil producing plants with up to 5 tonnes of oil per hectare, but soybeans also yield 500 kg of oil per hectare [7]. Protein meals represent the traditional target feedstock for production of soybeans. They are used in animal feed and mostly exported to industrialized countries. The exploding demand for biodiesel is currently inverting priorities: the FAO and OECD predict that the price of soybean oil will increase and the price of protein meal will decrease in the next 10 years [14]. In other words, the former target product "protein meals" is becoming a co-product, and oil demand will become a driver for deforestation.

Following the same way for demonstration, and taking into account that Brazilian forests store slightly less carbon than Southeast Asian ones [15; 16], it will take 450 years of soybean production and subsequent soybean oil derived biodiesel in Brazil to compensate on a given surface the greenhouse effect resulting from the conversion of aboveground rainforest biomass to agricultural land. The situation is therefore even more dramatic than with palm oil because soybean yield only a tenth of palms. The conversion of underground biomass as a possibly even greater source of carbon dioxide comes on top to worsen the picture.

Cerrado, savannas in central Brazil, are the main focus for conversion to agriculture in Brazil now. It induces the release of about 6.3 tonnes of carbon as carbon dioxide over a period of 10 to 20 years after conversion [17, 18]. Taking all energy that is needed for cultivation of soybeans, oil earning and transformation to biodiesel into consideration, it is only after 27.4 years, that a benefit could be retrieved from a climatic point of view.

Deforestation and soybean production already accelerated at the beginning of the decade in Brazil for other reasons. During the course of the mad cow disease, giving animal feed to cattle was forbidden, and the result was dramatically increased soybean production along with deforestation [19]. Changes in land use are responsible for 80% of greenhouse gas emissions in Brazil [20].

Rape serves as a third source of vegetable oils for biodiesel production in temperate regions. Because rape is grown on land that has been deforested long ago and not for this purpose, the greenhouse gas emissions associated with the conversion of forest to agricultural land may be neglected now. However, the production of rapeseeds requires energy for agricultural processes and for their transformation into biodiesel afterwards, and this energy must be taken into account in the energy balance. One hectare of rape yields roughly one tonne of biodiesel [7; 15; 16]. The gross calorific yield, consequently, is 37.8 gigajoules per hectare (equivalent to 880 kg diesel oil [9]). From this, an overall of 40% must be subtracted because such an energy input is necessary for crop production and the transformation process [21]. The net yield of energy available for transportation as fuel without greenhouse emission relevance is therefore not more than 530 kg mineral oil equivalent. It means that a substitution rate of 5.75% diesel with rapeseed oil biodiesel corresponds merely to a reduction of 3.8% of carbon dioxide emission with a fossil origin of carbon when material flows are considered from well-to-wheel.

The fermentation of starch contained in wheat requires an energy input that is equivalent to the output, assuming wheat grain yields of 6 t per hectare (This calculation is based on ethanol yield data [22], energy demand data for fermentation of cereals and energy demand for crop production [23]).

Actual carbon dioxide emission savings are much lower than expected

For ethanol, sugar beets are the most productive crops in Europe (7,000 litre with a gross fuel energy yield of about 150 gigajoules per hectare [24] and an estimated net yield of 36 gigajoules per hectare. A substitution rate of 5.75% gasoline with sugar beet ethanol corresponds to a reduction of not more than 2.3% of well-to-wheel fossil carbon emissions in the form of greenhouse gases.

Compared with doing nothing, the overall reduction of fossil carbon input from well-to-wheel will be no more than 3.5% when first-generation biofuels are substituted for conventional fuels for 5.75%. Referring to a share of 80% of the total primary energy demand provided with fossil fuels, the displacement effect for carbon compounds with fossil origin leading to greenhouse gases represents less than 1.5%. In contrast, the prospected growth rate is 14% for primary energy demand and 25% for transportation energy between 2005 and 2030 [25].

First-generation Biofuels Require Much More Land Than is Available to Achieve Significant Positive Climatic Effects

According to the European Environment Agency (EEA), the land available in Europe (EU-25) for biofuel crop production with limited negative environmental impacts amounts to about 15 million hectares in 2010 and up to 22 million hectares in 2020 [8].

On the other hand, the EU Directorate-General for Energy and Transport prospects a transport fuel demand of 388.6 Mio tOE in 2010 and 428 Mio tOE in 2020, representing 32.5% of the final energy demand [25].

Assuming transportation fuel demand is equally distributed among gasoline and diesel, the substitution of 10% of each with ethanol and biodiesel would require 32 million hectares, 1.5 times the land area that the EEA considers available in the EU for bioenergy crop production [26].

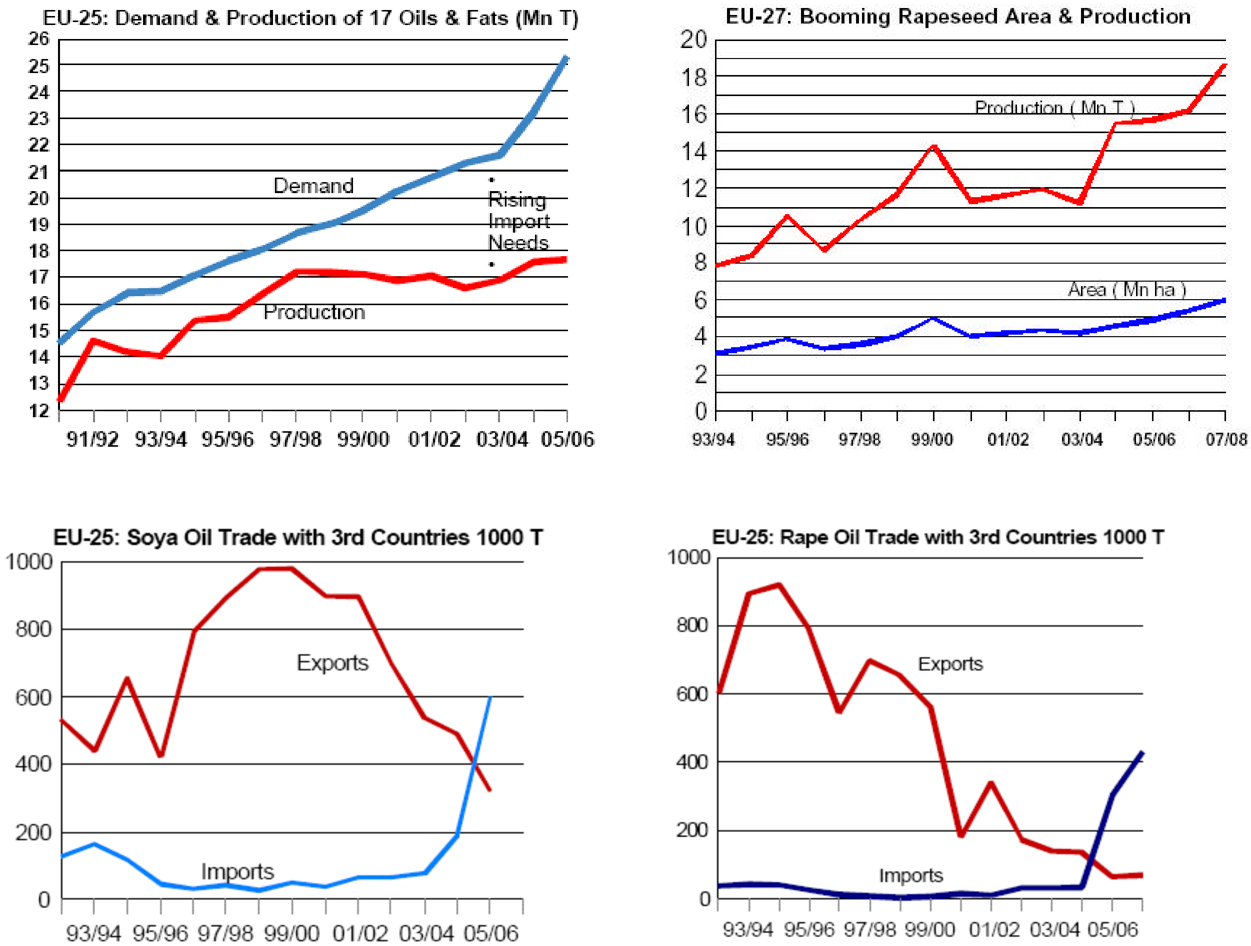
First-generation Biofuels Enhance Food Insecurity

About 15% of the world population (854 million people in 2001-2003) are chronically undernourished worldwide and according to the last progress report of the FAO, no progress has been made on the way to fulfil the goal defined at the World Food Summit in 1996 to halve this number until 2015 [27]. In that time, the European Environmental Agency assumed a reallocation of European surfaces currently producing food raw materials for exports to the production of crops for bioenergy for the calculation of the surface available to grow bioenergy crops mentioned above [26].

The world population amounts to 6.5 billion people today and is likely to rise to 8.2 billion in 2030 [28]. The worldwide average level of dietary energy supply for a current population of 6.5 billion people is 2,800 kcal per person and day [29]. FAO and WHO published the supply target of 3,050 kcal per person and day in a report in 2003 on diet, nutrition and the prevention of chronic diseases. Increasing the dietary energy supply to a world average of 3,050 kcal per person and day for a population that has risen to 8.2 billion people in 2030 [30] will require either a increase in land demand or an increase in productivity of agriculture of 37%. Another contribution to food security assurance consists of a drastic reduction of meat in the diet since the efficiency of transformation of vegetal energy to dietary energy in the form of meat is between 15% and 35% depending on the cattle considered [31]. First-generation biofuels are clearly impeding the realization of a human right for sufficient food.

Trading figures of Oil World / Ista Mielke, a forecasting service for the oilseeds, oils and meals industry, suggest that rapeseed oil and even soybean oil were supplying some of the demand for biodiesel already in 2001 [32]. According to these figures, EU-25 turned from a net exporter to a net importer of these vegetable oils in 2005.

Figure 2: Vegetable oils: Production, Demand, Import into and Export outside the EU



Source: [Ista Mielke, 32]

If the whole worldwide production of vegetable oils, sugar and cereals which are currently used as food were completely regarded as raw materials for biofuel production, a transport energy potential of 25 EJ would be generated per year. This corresponds to 32% of the worldwide demand in transport energy of 78,1 EJ in 2004 [33]. Contributions would be as follows:

EPEA

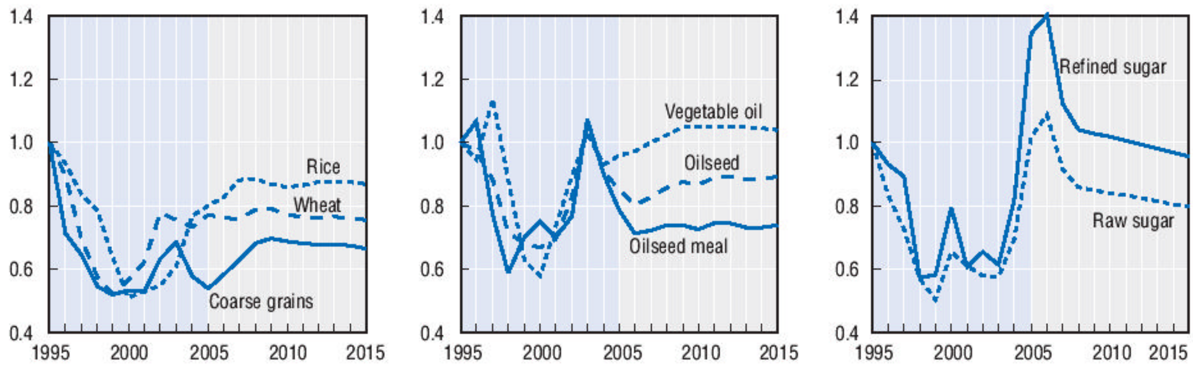
Figure 3: Biofuel potential of the main agricultural productions worldwide

	Yearly production (Mio t)	Biofuelenergy potential (EJ)
Vegetable oils	95.0	3.6
Sugar	145.0	2.0
Wheat	585.8	4.4
Maize	923.0	7.6
Rice	399.3	3.0
Other (guessed)		4.3
Total		**25.0**

First-generation Biofuels Create Poverty

The price of all edible crops, used for biofuel production has risen in the last years. It doubled for sugar between summer 2005 and fall 2006 [34]. It doubled between 2001 and 2006 for rapeseed oil [35] and increased by 22% between the last two production seasons for cereals [36]. FAO and OECD expect the price of these raw materials to further increase and to maintain a high level in the long-term. The only reasonable prediction is greater difficulty for an increasing share of the population worldwide to have access to food.

Figure 4: Outlook for World Crop Prices to 2015
(Index of nominal prices, 1995 = 1) Source: FAO and OECD secretariats [14]



First-generation Biofuels Contribute to Soil Degradation

Ten years ago, a global assessment of human-induced soil degradation (GLASOD) was made to prepare the already mentioned World Food Summit. Globally, land is lost for agriculture at a rate of 5 to 12 million hectares every year, due to overuse and a lack of proper management [37; 38].

The conversion of tropical rainforests to farmland is a well-known source of soil degradation leading farmers to move to new land when the soils have been depleted after a few years of agricultural production. This aspect is especially relevant for the annual crop soy, which is grown on former rainforest soils in South America.

The GLASOD showed that in Europe, 20% of soils used for agriculture, permanent pasture or forests and woodland were considered “seriously degraded”. This is the highest rate after Central America (31%) and just before Africa (19%).

In its survey of the potential for bioenergy crop production available in the EU, the EEA compares crops according to their contribution to soil erosion, soil compaction, groundwater contamination with nutrients and pesticides and water abstraction. They conclude that edible crops that are most efficient for first-generation biofuels (rape, sugar beet, maize) are exactly those that are most stressing soils [26].

First-generation Biofuels Accelerate the Loss of Biodiversity

The World Conservation Monitoring Centre of the United Nations Development Programme identifies biofuels as seeming to "inevitably lead to losses of biodiversity in the medium-term 2010-2050" [39].

After the analyses made above, it is clear that first-generation biofuels accelerate the loss of biodiversity. Firstly, biofuels exacerbate the spread of monocultures and the related use of pesticides, the function of which is to reduce biodiversity on monocultures areas. Secondly, biofuels drive deforestation of the very biodiverse tropical rainforests.

First-generation Biofuels Accelerate the Depletion of Scarce Resources

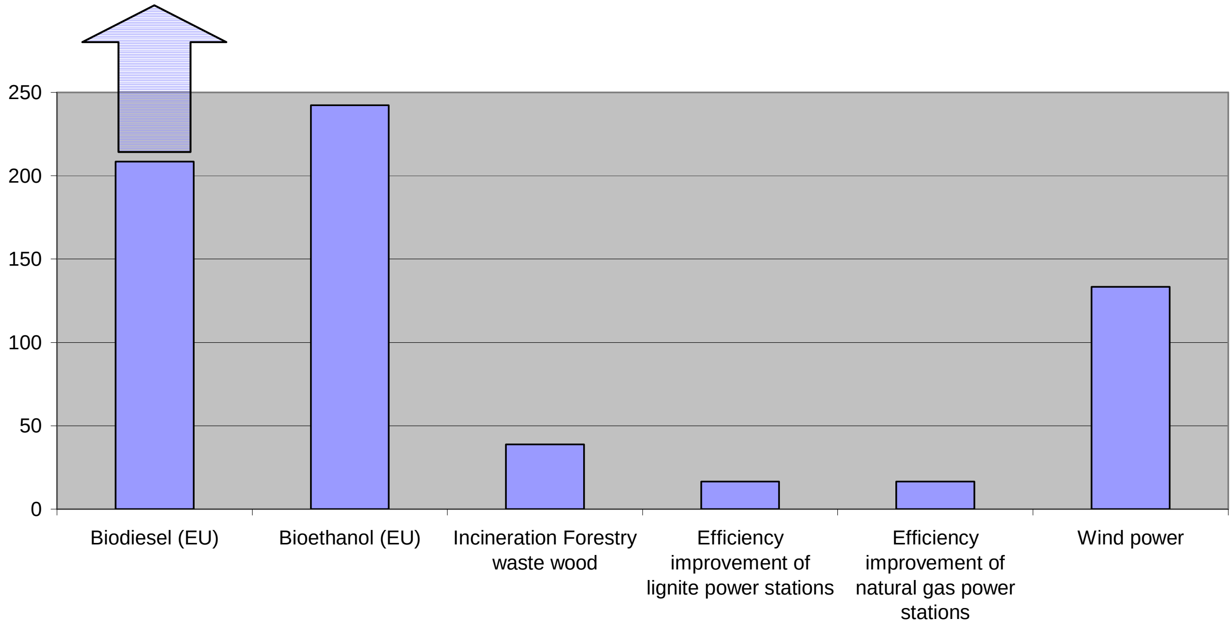
Monocultures and the instability of soils is related to a high demand for fertilizers. The case of phosphate fertilizers disserves special attention. Currently known mineral reserves suggest availability of phosphorous for 130 to 400 years depending on costs for their extraction. More urgent to consider than the availability of phosphorous is its quality. Phosphorous resources contain significant amounts of toxic heavy metals like cadmium, lead and uranium (up to 850, 300, 200 mg/kg of phosphorous, respectively) [40]. Phosphate reserves with low heavy metal levels (less than 60 mg cadmium/kg phosphorous) constitute not more than 15% of known reserves [41]. In other words, phosphorous reserves with low levels of heavy metals will be exhausted in less than 20 years if the current global rate of depletion of reserves (130 million tonnes per year) is maintained or increased in the future. Another side effect of the use of mineral phosphate fertilizers is the spread of radioactivity in the environment. Today, phosphate fertilizers are the main source of contamination of the environment with uranium that--like other heavy metals--accumulates in crops and in the food chain. Increasing a demand for the production of biofuels requires a concept for the supply of safe phosphorous.

If Effective as Carbon Dioxide Abatement Options, First-generation Biofuels are Not Cost Efficient

Investment in facilities for the generation of biofuels bind investment funds that will not be available anymore for implementation of measures and for research in technologies which are more supportive for the environment and lead to higher energy efficiency.

The German Rhine-Westphalian Institute for Economic Research reviewed the sustainability of biodiesel and revealed that it is tremendously cheaper to reduce greenhouse gas emissions by improving the efficiency of lignite or natural gas power stations than by substituting biofuels for conventional fuels for transportation.

Figure 5: Greenhouse gas abatement costs (€ / t GHG)



Source [42] and adaptation for biodiesel by authors.

It must be noted that the figure on biodiesel does not consider greenhouse gas emissions, which result from change in land use in tropical regions. They are responsible for a strong acceleration of greenhouse gas emissions rather than for their abatement. European biodiesel results from oils with mixed origins.

Further costs induced by biofuels are externalized in the form of:

- higher prices for food that will make it less affordable for an increasing portion of the population worldwide,
- decreasing health
- intensified requirements for water purification and soil decontamination
- vulnerability of monocultures against pest, fire and weather catastrophes as a factor for insecurity of biofuel supply
- military measures responding to tensions resulting from these stressing factors. These can be especially expected in lower-income countries that import grains, such as Indonesia, Nigeria, Mexico and others, which together could disrupt global economic progress (see the analysis of Lester R. Brown [31]).

Negative impacts of using first-generation biofuels significantly outweigh the benefits. Alternative options to first-generation biofuels are available to respond to the challenge of the greenhouse effect and climate change at lower costs:

- Any measure for energy saving is welcome as having no detrimental environmental effect. An 3.5% increase in the fuel efficiency vehicles or a 3% reduction in building heating demand (which can be accomplished with building insulation measures) has the same climatic effect as a 5.75% substitution of biofuels for conventional fuels.
- Fuels produced from perennial crops with a higher primary energy yield per hectare and processed in a way that the whole biomass may be transformed for usability will reduce drastically the intensity of stresses listed above. The option of using cellulose and lignin of poplar plantations for the generation of biomass-to-liquid fuels (BtL) is already better than any First-generation biofuel, even if poplars are cultivated in mono-

cultures. However, it still requires closer attention on whether this is a good path to meet the challenges that first-generation biofuels cannot meet.

- Any effort made to reforest degraded land with perennial plants contributes positively to the prevention of the climate change, the retention of water, the abatement of soil degradation and maintenance of biodiversity. Fruits to be obtained from these restored green surfaces could be used for biofuel production if land increases in agricultural productivity otherwise enable to supply enough food to the growing population.
- About 1.5% of the world surface is urbanized [43] and is a good candidate as sun collector without any additive pressure on food affordability, soils, biodiversity or fertilizer reserves.

Literature

1 Press Release of the Environmental Council of the European Union. Brussels, 20 February 2007. Internet: http://www.consilium.europa.eu/ueDocs/cms_Data/docs/pressData/en/envir/92864.pdf [21 Februar. 2007]

2 Anonym. 2003. Directive 2003/30/EC of the European Parliament and of the Council of 8 May 2003 on the promotion of the use of biofuels or other renewable fuels for transport. Official Journal of the European Union L 123/42. Internet: http://europa.eu.int/eur-lex/pri/en/oj/dat/2003/l_123/l_12320030517en00420046.pdf [3 Januar. 2007]

3 Anonym. 2007. Biofuels Progress Report. Report on the progress made in the use of biofuels and other renewable fuels in the Member States of the European Union. Communication from Commission of the European Communities to the Council and the European Parliament COM(2006) 845 final. Brussels, [9.1.2007]. Internet: http://eur-lex.europa.eu/LexUriServ/site/en/com/2006/com2006_0845en01.pdf [15 Januar. 2007]

4 Kembangan S. First shipment of biodiesel to Europe next week. The Star Online 11. August 2006. Internet: http://biz.thestar.com.my/news/story.asp?file=/2006/8/11/business/15112818&sec=business [Accessed January 8. 2007]

5 Anonymous: Sources of Dietary Energy Consumption 2001-2003. Edited by FAO Statistics Division. Internet: http://faostat.fao.org/site/345/default.aspx [Accessed January 4., 2007].

6 Wahid M. B., Abdullah S. N. A. and Henson I.E. 2005. Oil Palm – Achievements and Potential. Plant Prod. Sci. 8(3):288-297

7 Teoh Cheng Hai. 2004. Selling the Green Palm Oil Advantage? Oil Palm Industry Economic Journal 4(1): 22-30

8 Reijnders L. and Huijbregts M.A.J. Palm oil and the emission of carbon-based greenhouse gases. Journal of Cleaner Production (2006), doi:10.1016/j.jclepro.2006.07.054

9 Anonymous. Bioenergy conversion factors: Bioenergy Feedstock Development Programs at the Oak Ridge National Laboratory. Internet: http://www.localenergy.org/pdfs/Document%20Library/Bioenergy%20conversion%20factors.pdf [Accessed January 10., 2007]

10 Hooijer A., Silvius M, Wösten H. and Page S. 2006. PEAT-CO_2 Assessment of CO_2 emissions from drained peatland in SE Asia. Delft Hydraulics report Q3943 (2006)

11 Anonymous 2006. Southeast Asia's peat fires and global warming. Edited by Biofuelwatch. Internet: http://www.biofuelwatch.org.uk/peatfiresbackground.pdf [Accessed February 16. 2007]

12 The present carbon cycle. United Nations Environmental Program. http://www.grida.no/climate/vital/13.htm [accessed 2006, 12. 21st]

13 Lal R. Global Potential of Soil Carbon Sequestration to mitigate the Greenhouse Effect. Critical Reviews in Plant Sciences 2003:22(2):151-184.

14 Anonymous. 2006. OECD-FAO Agricultural Outlook 2006-2015. Internet: http://www.agri-outlook.org/dataoecd/41/21/37038911.pdf [Accessed January 3., 2007]

15 Asendorpf D. Erwachen am Amazona. Die Zeit. 2006:51:41-42

16 Fearnside P.M. Greenhouse Gases From Deforestation in Brazilian Amazonia: Net Committed Emissions. Climatic Change 1997:35/3:321-360

17 Costa E. A., Goedert W J, Souda D M G. de. Soil quality under tillage and non-tillage cropping systems. Pesq. agropec. Bras., 2006:41:7:1185-1191

18 Green V.S., Stott D.E. Cruz J.C., Curi N.: Tillage impacts on soil biological activity and aggregation in a Brazilian Cerrado Oxisol. Soil & Tillage Research 2007:92:114-121

19 Braungart M., Soth J. Parusel D. Eickhoff U. Haeling C. Hengst H. and Lange J. 2002. Umwelt- und Sozialfolgen des Verfütterungsverbotes für tierische Proteinmehle. Books on Demand GmbH, Norderstedt.

20 Anonymous. Carbon Dioxide Emissions by Source 2005. Edited by Carbon Dioxide Information Analysis Center (CDIAC), World Resources Institute (WRI). Internet: http://earthtrends.wri.org/pdf_library/data_tables/cli3_2005.pdf

21 Scharmer K. 2001. Biodiesel. Energie- und Umweltbilanz von Rapsölmethylester. Edited by Union zur Förderung von Öel- und Proteinpflanzen e.V. Internet: http://www.senternovem.nl/mmfiles/26611_tcm24-124163.pdf [Accessed January 12. 2007]

22 Senn T. 2003. Die Produktion von Bioethanol als Treibstoff unter dem Aspekt der Energie-, Kosten- und Ökobilanz. Edited by Forschungsverbund Sonnenenergie. Internet: http://www.fv-sonnenenergie.de/fileadmin/fvsonne/publikationen/ws2003/02_c_Bioethanol_01.pdf [Accessed January 10., 2007]

23 Senn T. and Lucà S.F. Studie zur Bioethanolproduktion aus Getreide in Anlagen mit einer Jahres-Produktionskapazität von 2,5 und 9 Mio. Litern. Eine Energie und Kostenbilanz. Edited by the Bundesverband landwirtschaftliche Rohstoffe verarbeitende Brennereien e.V. Internet: http://www.uni-hohenheim.de/gaerung/dateien/Gesamtstudie%20120503.pdf [Accessed January 10., 2007]

24 Anonymous. Bioethanol aus Zuckerrüben. Chancen für den Zuckeranbau. Edited by KWS Saat AG. Internet: http://www.kws.de/global/show_document.asp?id=aaaaaaaaadneah [Accessed January 11., 2007]

25 Anonymous 2003. EU-25 Energy and Transport Outlook To 2030. Part IV. European Commission. Directorate-General for Energy and Transport. Internet: http://ec.europa.eu/dgs/energy_transport/figures/trends_2030/5_chap4_en.pdf [Accessed 2006, Dec. 22)

26 Anonymous. How much bioenergy can Europe produce without harming the environment? Report 7/2006. European Environment Agency. Copenhagen. Internet: http://reports.eea.europa.eu/eea_report_2006_7/en/eea_report_7_2006.pdf [Accessed 2006, Dec. 22]

27 Anonymous 2006. The State of Food Insecurity in the World 2006. Eradicating world hunger – taking stock ten years after the World Food Summit. Edited by the Food and Agriculture Organization. Internet: ftp://ftp.fao.org/docrep/fao/009/a0750e/a0750e00.pdf [Accessed January 2., 2007]

28 Anonymous 2005. World Population Prospects: The 2004 Revision. Edited by the United Nations. New York. Internet: http://www.un.org/esa/population/publications/WPP2004/2004Highlights_finalrevised.pdf [Accessed January 2., 2007].

29 Anonymous: Sources of Dietary Energy Consumption 2001-2003. Edited by FAO Statistics Division. Internet: http://faostat.fao.org/site/345/default.aspx [Accessed January 4., 2007].

30 Anonymous. 2003. Diet, Nutrition and the Prevention of Chronic Diseases. WHO Technical Report Series 916. Report of a Joint WHO/FAO Expert Consultation. Internet: http://www.fao.org/DOCREP/005/AC911E/AC911E00.HTM [Accessed January 4., 2007].

31 Brown, L., Hindmarsh, R., Mcgregor, R., 2001. Dynamic Agriculture Book Three (2nd ed.). McGraw-Hill Book Company, Sydney.

32 Oil World. Edited by ISTA Mielke GmbH. Hamburg Germany

33 Anonym. Key World Energy Statistics 2006. Edited by the International Energy Agency. Internet: http://www.iea.org/dbtw-wpd/Textbase/nppdf/free/2006/key2006.pdf [Accessed 2006, Dec. 22]

34 Anonymous. International sugar statistics. Website of the company Illovo Sugar Limited. http://www.illovosugar.com/worldofsugar/internationalSugarStats.htm [Accessed January 4., 2007

35 Unilever, Personal communication

36 Anonymous. Global Derivatives Research / Grains. Edited by Prudential Financial Derivatives, LLC. Newark, NJ, USA. September 12, 2006

37 Scherr S. J. Soil Degradation - A Threat to Developing-Country Food Security by 2020? Food, Agriculture, and the Environment Discussion Paper 27. International Food Policy Research Institute

38 Anonymous. 1996. Human-Induced Soil degradation. Edited by the Food and Agriculture Organization. Internet: http://www.fao.org/docrep/003/w2612e/w2612eMap12-e.pdf [Accessed 2006, Dec. 22]

39 ten Brink B. et al. 2006. Cross-roads of Planet Earth's Life. Exploring means to meet the 2010 biodiversity target. Study performed for the Global Biodiversity Outlook 2. Edited by the Netherlands Environmental Assessment Agency. On behalf of the United Nations Environmental Programme. Report MNP 555050001/2006.

40 Anonymous: Extracts Reviews of Environmental Issues. International Fertilizer Industry Association. http://www.fertilizer.org/ifa/topics/water_2003/PDF/extracts_4.pdf [January 15. 2007]

41 Anonym: Comments from the International Fertilizer Industry Association (IFA) on the Draft of the European Commission (EC) Proposal Relating tô Cadmium in Fertilizers. 2002. http://europa.eu.int/comm/enterprise/chemicals/legislation/fertilizers/consultation/contributions/26.doc [Accessed Nov. 2003]

42 Frondel M. and Peters J. Questioning the sustainability of Biodiesel. Edited by the Rhine-Westphalian Institute for Economic Research. October 2005

43 Anonymous. Earth. Landuse. Wikipedia. Internet: http://en.wikipedia.org/wiki/Earth#Land_use. [Accessed January, 15. 2007]