AGROTECHNOLOGY & FOOD SCIENCES GROUP
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Biodiesel from Brazil

Report for the Dutch Ministry of Agriculture, Nature and Food Quality

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With contributions from Sarah Stattman (Wageningen University)

Report BO-CI-35

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Executive summary

The EU Biofuels Directive (2003/30/EC) sets a target of replacing 5.75% of transport fuels by bio-fuels in 2010 (19 TOE biofuels in 2010. The EU proposed Renewable Energy Directive calls for 10% biofuels in 2020 requiring (36 TOE biofuels). Though targets have been decreased recently (NL and DE) it is expected that a significant part of the biodiesel (or feedstock) will have to be imported. Brazil has proven with bioethanol that it can implement biofuels that can compete with existing petroleum fuels and should be one of the main potential biodiesel suppliers. For a mature trade relationship to exists biodiesel will have to comply with EU sustainability and quality demands.

The EU and Brazilian biodiesel demand
In the EU the primary objective of biofuels is to increase security of supply and to reduce Green House Gas (GHG) emissions. Incidents show that bioenergy and biofuels do not by definition comply with these goals. This has led to the development of principles and criteria for biofuel sustainability. The 'Cramer Criteria' in The Netherlands set goals in the area of GHG emissions, competition with food and other products, biodiversity, environment, prosperity, welfare (health). The proposed EU Renewable Energy Directive stipulates that incentives for bioenergy and biofuels can only be obtained if sustainability criteria are met in 4 areas; Greenhouse gas impact, Land use/carbon stock, Biodiversity and Environmental requirements for agriculture. An analysis for conformity with EU and WTO regulations showed that demands with respect to GHG emissions are possible while demands with respect to competition and economic prosperity and well-being are deemed impossible. Demands with respect to biodiversity, soil, air, water are difficult to implement in conformity with WTO and EU regulations. Indirect land use change effects (resulting from competition for commodities or for land leading to GHG emissions and biodiversity loss) are not (yet) dealt with effectively in the proposed sustainability criteria.

The Brazilian biodiesel program
In the coming years Brazil will be developing its own biodiesel infrastructure and market which will require much of its resources. The Brazilian Biodiesel programma has a strong focus on social inclusion. Compulsory biodiesel blending have been set at 2% (B2) in 2008 increasing to 5% (B5) in 2013, requiring 1 billion liters of biodiesel in 2008 and 2.4 billion liters in 2013. It may be expected that soy will be the main feedstock in the coming years as other options like oil palm and Jatropha require some time to develop. This should also be the main export option at this moment.

Biodiesel quality criteria
International trade of biofuels and its raw materials depends on the availability of good fuel quality standards. The European standard for biodiesel, EN 14214, is the most

demanding in the world. Only rapeseed methyl ester of high purity is accepted as biodiesel, either as a neat fuel or in blends (up to 5%) in petrodiesel (EN 590). Common vegetable oils from crops that are widely used in Brazil do not comply in their pure form to the European standard. Only blending of different methyl esters (*e.g*. from soy and palm) seems to be a realistic option. New less strict standards will allow for more feedstock flexibility, and selection of the most attractive raw materials from a cost, quality and sustainability point of view. Second generation technologies that can transform low cost biomass (lignocellulosic material = fibre) into high quality fuels may become an alternative to oil based biodiesel in the coming years. As this feedstock is much more available than vegetable oil it, should be possible to produce larger biofuel quantities in a sustainable way.

Impact of crop cultivation

The GHG balance demands plus the CO_2 tools may help buyers of oil for biodiesel and producers to put measures into effect that reach the GHG balance demands. The effort should not be underestimated and may add to the price of biodiesel. Most problematic is the (often indirect) clearing of new land for the cultivation of soybean or other perspective biodiesel crops. As biofuels will certainly have to contribute to a decrease in GHG emissions a decoupling of crop production (for biofuel) from negative land use change (deforestation, wetlands destruction) is absolutely necessary (as is the case for any energy crop anywhere in the world). Proper land use planning is undoubtedly the most effective way to find optimal combinations for balancing the social, economic and environmental objectives that should be realised in the Cerrado and also in the Amazon region. It will remain unsatisfactory if maximization of one objective, e.g. maintaining all natural lands, would go at the expense of economic development. Ideas have been put forward which centre around increasing pasture use intensity by 10 to 20% by integrating pasture and crop production, thus freeing up land for biofuels. Though the system could technically work the big question remains how implementation can take place and to what extent this development can release enough land both for additional food and feed production and for biofuels and thus isolate increased demand from deforestation. As for GHG demands, other Cramer and EU criteria, such as loss of biodiversity, efficient use of water, will not be met under a business as usual scenario.

We argue that sustainability demands will first focus on GHG performance of biofuel as this is a primary driver for biofuels in the EU and it is a demand that can be set under WTO and EU regulations. GHG performance can in principle be quantified in an objective way, though much needs to be assessed and developed. Methods and cost effective certification will have to be implemented and producers may have to adapt production systems. Challenges lie in agreeing on methods for GHG assessment especially for indirect effects.

Introduction to the project

The EU has set specific targets (5,75% in 2010) for replacement of fossil transportation fuels by bio-fuels and has plans to set a 10% target for 2020. It is expected that imports of bio-fuels will be required in order to meet these targets. This applies to The Netherlands and also to the rest of Europe when even higher targets will be set in the near future. In some other visions up to 40% of transportation fuels are projected to be bio-fuels[1]. The Netherlands with its large harbor, agribusiness and oil refinery infrastructure is already playing a large role in importing, processing, conversion and (re)-distribution of biofuels, especially of ethanol.

Brazil already is an important producer and exporter of ethanol and also has the potential and the ambition to become an important exporter of biodiesel (or its feedstocks) to Europe and the Netherlands in particular. In order to tap into this potential a number of complicated obstacles have to be taken. Brazil has a well developed ethanol industry which is the main alternative to gasoline. The development of bio-diesel is in an earlier stage of development. Many issues in the field of technology and sustainability remain to be solved especially if the volume is to become of a significant size. Extensive studies exist on Brazilian ethanol production. Bio-diesel production and export is still under development but may have a potential as large as ethanol. The Dutch Ministry of Agriculture, Nature and Food Quality has therefore asked for a research project to be performed that examines the technical and environmental demands on and potential for biodiesel export to The Netherlands and the EU.

Objectives

- Identify who the stakeholders are and what their roles are in the bio-diesel production chain from field production in Brazil to consumption in The Netherlands (and EU).
- The current status and performance of Brazilian bio-diesel production and a comparison to the technical and sustainability requirements for exporting to The Netherlands.
    - To set up a research agenda on sustainable bio-diesel production and initiation of a corresponding research collaboration.
    - Execution of a case study into a selected bio-diesel chain which may help to implement business strategies.

[1] Platform Groene Grondstoffen, 2006.

Approach
The project has been divided into four parts.

In the first part an overview is given op biodiesel demand in The Netherlands and Europe together with an introduction to Brazilian biodiesel policies and potential for production and export of biodiesel now and in the future.

In the second part technical issues related to biodiesel are presented to answer the question how Brazilian biodiesel can comply with EU quality demands – now and in the future?

The third part of the report focuses on sustainability of biodiesel production with special focus on soya and on the topic of direct and indirect land use changes of biodiesel demand which have green house gas (GHG) and biodiversity effects.

In part four a case study is presented on production of palm oil biodiesel in Brazil which gives an overview of the potential for palm oil production and the hurdles that palm oil based biodiesel may face.

In annex 2 a report is presented on the workshop held in The Hague. The workshop aimed to put biodiesel and biofuels into perspective and was used to formulated a joint research agenda with Brazilian (EMBRAPA) researchers, the project team and other participants of the workshop.

Part 1. Biodiesel in Brazil: Policies, resources and options for export to the EU

Wolter Elbersen
Prem Bindraban

1 Introduction

In the first part an overview is given op biodiesel demand in The Netherlands and Europe together with an introduction to Brazilian biodiesel policies and potential for production and export of biodiesel now and in the future.

1.1 Objective

The objective of part of the study was to describe the current situation of biodiesel in the EU as related to importing biodiesel and the biodiesel context in Brazil and give an introduction to parts 2 and 3 which deal with technical biodiesel issues and with sustainability.

Find out which technical barriers have to be overcome before Brazilian biodiesel can enter the EU market and comply with EU quality standards. Research questions that will be answered are:

- *How can the biodiesel demand from the EU be characterized?*
- *What is the status of Brazilian Biodiesel production?*
- *What (crop) options exist for biodiesel production in Brazil?*
- *What options exist for export of biodiesel to the EU?*

1.2 Approach

Information was gathered by literature study and interviews with experts in Brazil and the Netherlands.

2 The demand for biodiesel in the EU and the Netherlands

2.1 The EU biofuels directive and new regulations

The main drivers for bioenergy production in the EU are sustainability and security of energy supply. On top of this, secondary drivers can be identified such as rural employment, new economic opportunities, etc [2] and [3]. Sustainability is mostly focused on mitigation of climate change and thus on the reduction of Green House Gas (GHG) emissions compared to fossil fuel alternatives. For the Netherlands reduction of CO_2 emissions from the transport sector is the main driver for introduction of biofuels (IEA, 2007).

In 2003 the EU passed the Biofuels Directive (2003/30/EC) which sets a target of replacing 5.75% of transport fuels by bio-fuels in 2010 (on an energy basis). More recently the EU proposed new Renewable Energy Directive (EU, 2008) which calls for 10% biofuels in 2020. In Table 1.1 current and forecasted biofuel demand is given.

Table 1.1. Estimated biofuel demand in the EU in 2010 under current (5,75%) and new (10%) biofuel replacement targets for 2020 (10%). (Based on EC-DGTREN, European Energy and Transport Trends to 2030, European Commission Directorate-General for Energy and Transport, Brussels, 2003).

Year	**2010**	**2020**
	Mtoe	**Mtoe**
The Netherlands	0.68	1.35
Belgium	0.50	0.94
Germany	3.76	7.04
Sweden	0.39	0.70
United Kingdom	2.51	4.70
EU27	**19.00**	**36.2**

To what extent these goals will be reached is uncertain considering the current high vegetable oil prices and discussion on biodiversity, GHG impact and competition with food. The EU Commission (EU 2008) recently reported that a 4,2% biofuel replacement is

[2] http://ec.europa.eu/energy/energy_policy/documents_en.htm.
[3] JRC. 2008. Biofuels in the European Context: Facts and Uncertainties.

expected by 2010 compared to the goal of 5,75% in 2010. The USDA forecasts that only 3,75% biofuel will be attained in 2010 (USDA, 2008).

The import needs have been estimated by MVO and Fediol (MVO, 2006) before the surge in commodity prices. It was estimates that by 2010 the EU vegetable oil demand (rape seed oil) for biodiesel would be 11,1 million tons and the food demand 2,9 million tons per year. This would lead to a production shortfall of 3,8 to 4,5 million tons by 2011. Even if the biofuel objectives are only reached partially a significant amount of the biodiesel or feedstocks will have to be imported from outside the EU in the coming years and are already being imported (i.e. rapeseed and soy). Biodiesel imports have already taken off considerably in recent years, mainly due to the $1 (€0.72) a gallon subsidy to biodiesel producers, by a procedure known as 'splash-and-dash'; where biodiesel from Latin America and elsewhere is shipped to the US, blended with a tiny amount of mineral oil and re-exported to the EU[4]. In 2007 between 0,750 and 1 million tons of this biodiesel was imported from the USA to the EU (EBB, 2008; USDA, 2008).

Biodiesel production in the EU was 5,7 million tons in 2007 compared to 4,9 million tons in 2006 (EBB, 2008). At the same time 3 million tons of biodiesel production capacity were idle in 2007. This was due to imports from the US as mentioned above, high feedstock prices and a slowing of market demand especially in Germany and an anticipation of further market growth. By the middle of 2008 16 million tons of biodiesel production capacity divided over 330 plants are expected to be in operation (EBB, 2008). This would mean that the biodiesel production capacity in the EU would likely be higher than the most optimistic demand expectation for 2010. If the total (5,75%) biofuel replacement target would be reached and 75% of the biofuel demand would be filled by biodiesel (see Table 1.1) not more than 15 million tons of biodiesel would be required in 2010 in the EU. In the current market smaller plants are being put out of production already. The current and expected overcapacity of the EU biodiesel industry and the relative shortage of feedstocks should lead to a much stronger demand for feedstocks than for biodiesel in the EU. The trade issues involved in this are beyond the scope of this project.

The Netherlands

The Netherlands has committed itself to implementing the EU biofuels and it has set the following targets:

- 2% in 2007, of which a minimum of 2% in diesel and gasoline
- 3,25% in 2008, of which a minimum of 2,5% in diesel and gasoline
- 4,50% in 2009, of which a minimum of 3,0% in diesel and gasoline
- 5,75% in 2010, of which a minimum of 3,5% in diesel and gasoline

[4] www.ebb-eu.org/.

This would require 0,68 MTOE biofuels in 2010. In September 2008 these compulsory biofuels targets were reduced from 5,75% to 4% in the Netherlands[5]. In Germany the compulsory targets were reduced from 6,25% to 5,25 in October 2009[6].

In 2007, 0,7 million tons of biodiesel were imported and 0,5 million tons were exported from Rotterdam. It is expected that Rotterdam and other harbors in The Netherlands (and Belgium) will become an important point of entry for biofuels or biodiesel feedstocks into Europe. Feedstocks will be converted in the biodiesel plants in Rotterdam and biofuels will be stored, used locally for blending in local refineries and is also shipped further up-river or to smaller ports in Europe.

For the Netherlands, EBB (2008) expects 0.571 million ton production capacity installed by the middle of 2008 while MVO (2007) expects 2,5 million tons of biodiesel production capacity by 2009. The high expansion of production capacity in the Netherlands is due to proximity to ports for import and export and proximity to fuel distribution networks and existing refineries. To what extent this capacity will be put into operation is unclear under the changing market condition at the moment.

2.2 Biofuel sustainability demands in the EU and in the Netherlands

The sustainability demand on biofuels in the EU and the Netherlands has become a very complicated and heavily discussed subject in recent years. (Both at the EU level and individual member state level) NGOs, industry, scientists and politicians are heavily involved in the discussion. As discussed above biofuels have a primary objective in providing an alternative to fossil fuels and oil in particular for reason of security of supply and for reducing GHG emissions. Other, secondary, drivers are development of a knowledge based industry creating jobs, economic growth, competitiveness and regional and rural development (EU, 2006).

The first sustainability discussions centered around the primary objectives of energy and GHG efficiency of biofuels illustrated by publications by Pimentel and others. Other sustainability aspects such as biodiversity loss and social aspects were also questioned as a result of discussions about the sustainability of using palm oil for electricity production in the Netherlands (Block, 2007; IUCN, 2008). As a result of increasing commodity prices in recent years the effect of competition with food and feed was highlighted as the (in)direct negative GHG effect which resulted from land use changes. As it slowly became clear to the wider public that bioenergy production is not by definition

[5] www.mvo.nl.
[6] Idem.

sustainable; different organizations, companies and governments moved towards developing certification systems that should help in ensuring that bioenergy and biofuels are produced in a sustainable way (Cramer *et al.*, 2007, Dam *et al.*, 2008; Dehue *et al.*, 2007).

In this respect the most relevant and visible development in the EU has been the so called 'Cramer criteria' in the Netherlands. These sustainability criteria have been defined jointly by government, NGO and industry representatives in the Netherlands and have become the starting point for Dutch policy in this area (Cramer *et al.*, 2007). The criteria have been set up in a non-discriminatory way and should apply equally to national, EU or imported biomass and biofuels. The working group defined six sustainability themes (Green House Gas emissions, competition with food and other applications, biodiversity, environment, prosperity and social well-being) which was translated into 9 principles:

1. The GHG balance of the production chain and application must be positive
2. Biomass production must not be at the expense of important carbon sinks in the vegetation and in the soil
3. The production of biomass for energy must not endanger the food supply and local biomass applications (energy supply, medicines, building materials).
4. Biomass production must not affect protected or vulnerable biodiversity and will, where possible, have to strengthen biodiversity.
5. In the production and processing of biomass the soil and soil quality must be retained or even improved.
6. In the production and processing of biomass ground and surface water must not be depleted and the water quality must be maintained or improved.
7. In the production and processing of biomass the air quality must be maintained or improved.
8. The production of biomass must contribute towards local prosperity.
9. The production of biomass must contribute to the social well-being of the employees and the local population.

These principles have been translated into criteria for which indicators and minimal requirements and reporting obligations are being defined. Existing systems (FSC, RSPO, etc) should cover many of the criteria defined for biofuels though new systems/methods will also have to be developed for issues such as GHG and energy balances, and land use change (Dam *et al.*, 2008). An example are the CO_2 tools that have been developed for calculating the GHG impact (within the chain)[7] according to specified methodologies. Currently a gradual process of implementation is envisioned in which a reporting obligation will be introduced first. Gradually GHG demands will be implemented starting with a 35% minimal GHG demand. Methodologies have been developed that specify how

[7] http://www.senternovem.nl/duurzameenergie/publicaties/publicaties_bio-energie/co2_tool.asp.

GHG emission are calculated and compared to fossil fuel in order to calculate GHG efficiencies.

EU and WTO conformity

It is important to realize that sustainability criteria only are of value if they can be implemented. Governments are limited in setting sustainability demands due to WTO and EU regulations which aim to limit trade impediments and discriminatory regulations. Individual companies can fine tune their demands (as is the case with coffee and other products). Minimal sustainability demands set by individual governments and by the EU should not conflict with EU and WTO law and regulations. The Cramer principles (9) have been analyzed for conformity with EU and WTO regulations (Bronckers *et al.*, 2007). In short it was concluded that:

- Demands with respect to GHG emissions (principles 1 and 2) are possible under WTO and EU regulations and can be applied to the blending obligations (in a non-discriminatory way).
- Demands with respect to competition (principle 3) and on economic prosperity and well-being (principles 8 and 9) are deemed impossible under WTO and EU law, except for extreme cases (i.e. slavery).
- Demands with respect to biodiversity, soil, air, water (principle 4 to 7) are difficult to implement in conformity with WTO and EU regulations.

The implementation of (minimal) sustainability criteria should have a substantial trade impact (USDA, 2008). This is due to that fact that many biofuel and biodiesel production chains will not be able to proof their GHG balance or analysis will show that the GHG is worse than the cut-of of 35% (or higher depending on the minimal standard).

New EU sustainability demands

The development of minimal (biofuel) sustainability demands has moved to the EU level with incorporation of sustainability criteria into the proposed renewable energy directive (EU, 2008; Maniatis, 2008). Under the directive incentives can only be obtained if sustainability criteria are met in 4 areas; Greenhouse gas impact, Land use/carbon stock, Biodiversity and Environmental requirements for agriculture. The system should be based on internationally accepted norms and should be non-discriminatory i.e. WTO compatible. The planned directive also stipulates that Member States must apply the criteria laid down in the Directive and that Member States may not lay down criteria that go further. The penalties for not fulfilling the criteria should be that the biofuels do not count towards EU targets, the biofuels do not count towards national biofuel obligations and biofuels may not benefit from tax exemptions and similar financial support (Maniatis, 2008).

Indirect land use change effects which are a result of competition for commodities or for land (Dehue, 2006 and 2007; Searchinger, 2007; Fagione, 2007; and others) and which are very difficult to quantify are not dealt with effectively in the proposed sustainability criteria (not by the EU and not by NL). Indirect land use can be described as the shift of the land use prior to biofuel production to another area where a land use change occurs due to maintaining the previous level of (food) production. This is also called 'leakage' or 'displacement' [8]. These indirect effects are illustrated in part 3 (for soy) of this report and in part 4 (for palm oil) and are large enough to determine sustainability of biofuels and should therefore be assessed. It must be stressed that increased biomass production in Europe may also induce deforestation (i.e. in Latin America), though indirectly.

[8] http://www.oeko.de/service/bio/dateien/en/ghg_balance_bioenergy.pdf.

3 The Brazilian biodiesel program

3.1 Biofuel history and policies in Brazil

Brazil is well known for its very successful sugar cane ethanol program which was initiated in 1975 and which in 2007 replaced 50%[9] of gasoline (by volume). In 2007 19 billion liters of fuel ethanol were produced in Brazil[10]. 800 million liters out of a total export of 3,5 billion liters were exported to The Netherlands in 2007. With more than 5 million flex-fuel vehicles and up to 26% blending in gasoline the Brazilian fuel ethanol industry has become a mature industry which is an example for the world and for the emerging biodiesel industry in Brazil.

Current Bioenergy policy goals are probably best described in the recent Guidelines for Agro-energy Policy 2006-2011 (MAPA *et al.*, 2005) which was launched in 2005 by the Ministries of Agriculture (MAPA), Science and Technology (MCT), Mining and Energy (MME) and the Ministry of Development, Industry and Foreign Trade (MDIC). The purpose is to give direction to public policies and actions towards the development of renewable energy sources and expansion of their share in the Brazilian energy matrix. The following goals for bioenergy can be derived from the document:

- Development of agro-energy through expansion of the ethanol sector,
- Implementation of the biodiesel production chain,
- Expansion of forests grown for energy production (i.e. eucalyptus plantations) and use of agro-forestry waste;
- Expansion that does not affect the production of food for domestic consumption, particularly of staple food;
- Technological development that promotes competition, reduces environmental impacts and contributes to economic and social inclusion, including the use of energy biomass in small scale; community-wide energy autonomy, particularly in more remote areas;
- Generation of jobs and income (development towards the interior of the country, social inclusion, reduction in regional disparities, etc);
- Optimization of the use of 'anthropized' areas, i.e. respect for the sustainability of production systems and discouraging the 'unjustified expansion of the agricultural frontier' or the advance towards systems such as the Amazon or the Pantanal;
- Optimization of regional vocations;
- Brazilian leadership in the international trade of agrofuels and 'adherence' to the national environmental policy and integration in the Clean Development Mechanism of the Kyoto Protocol.

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9 http://www.agropecuariabrasil.com.br/anp-estima-que-consumo-de-alcool-supere-gasolina/.
10 http://www.ethanolrfa.org/industry/statistics/#E.

In 2004 Brazil initiated a new program to develop biodiesel which is still in its infancy compared to the ethanol program. As stated by one of the interviewed experts in Brazil; 'Ethanol is a product, biodiesel is a project'.

3.2 Biodiesel policies in Brazil

Diesel has a very different market in Brazil than gasoline (and ethanol). The annual diesel consumption in Brazil is approximately 36 million m3 (2005) of which 20% is imported. 80% of the diesel is used for heavy transport while 20% is used in agriculture, for emergency electricity production and for electricity production in isolated areas which lack electric grid connection (Rocha and Cortez, 2005).
Already in the 1940's research and experiments were conducted in Brazil on using oils and fats from crops such as babassu, coconut, castor and cotton seed as fuels (Pousa *et al.*, 2007). Again in the 1970's research was started on biodiesel and in the 1980's there were initiatives to develop biodiesel as has been done with ethanol. These initiatives were not implemented and the research program was abandoned in 1984 (Alameida *et al.*, 2008).

In December 2004 a new National Program for Production and Use of Biodiesel (PNPB) was launched which is the basis of current biodiesel development in Brazil (Pousa *et al.*, 2007; Alameida *et al.*, 2008). The program has two main objectives (Alameida *et al.*, 2008; Pousa *et al.*, 2007):

- Fuel supply diversification and
- Social inclusion and regional development.

Other (secondary) drivers for the biodiesel program that can be found in documents include adding value to the soy production chain; Soy oil (is/was) a by-product of protein production leading to an oil surplus which explains the relatively low price in Brazil. For isolated areas which often use diesel for electricity production local biodiesel production provides a specific opportunity because of the high logistics cost of fossil diesel in these areas. Another secondary driver is the opportunity biodiesel provides in reducing air pollution in metropolitan areas because of the reduction in polluting emissions (except for NOx) when biodiesel is added to diesel.

As part of this program (PNPB) law no 11.097 was adopted (January 13, 2005) mandating a blend of 2% of biodiesel (B2) in the mineral diesel in 2008 increasing to 5% (B5) in 2013. This will require 1 billion liters of biodiesel in 2008 and 2.4 billion liters in 2013.

Biodiesel is expected to create 200.000 new jobs mainly for small farmers for this purpose. Another law was passed in 2005 (Law 11.116/2005) which regulates federal tax exemptions for fuel producers that source certain types of feedstocks from small farmers in certain regions and gives access to cheaper credit lines (Alameida *et al.*, 2008; Pousa *et al.*, 2007; Aceveido Rodriguez, 2007), the 'Social Fuel Certificate'[11]:

- 31% tax exemption is given to biodiesel from produced from castor and palm oil in the North and Northeast regions.
- 68% tax exemption is given to biodiesel produced in small family based agriculture
- 100% tax exemption is given to a combination of the two above.

Soybean biodiesel is excluded for tax exemption (Alameida *et al.*, 2008).

3.3 Biodiesel production capacity

The Brazilian biodiesel industry was recently reviewed by Alameida *et al.* (2008), Nagib (2006) and Gazzoni (2007). The industry is setting up capacity at a very fast rate. At the end of 2007 there was approximately 1,5 million liters installed capacity, 2 million liters were under construction, and 2 million liter capacity was being projected (Gazzoni, 2007). By 2009 there would be 4 Billion liters of installed capacity (Alameida *et al.*, 2008). Overall this would add up to almost 6 billion liters capacity in the near future which is more than the 2,4 billion liters mandated for 2013 in Brazil. Most plants use classical transesterification technology and methanol (Alameida, *et al.,* 2008) (see also part 2).

Most plants are projected to use a range of feedstocks but mainly use soy oil as a feedstock (Alameida *et al.,* 2008). There are also reports that some plants are commissioned but not operational due to high vegetable oil prices or use low cost oil/fat such as tallow. As is already observed in Europe overcapacity and high feedstock prices may also lead to a form of shake out and this should lead to larger average production units. The cost of investment almost doubles from 250$ per m3 per year for a 120.000 ton per year installation to 400$ per m3 per year for a 5000 ton per year installation (Nagib, 2006). Still, some 80% of the biodiesel cost is due to feedstock cost. This makes biodiesel very dependant on commodity market prices.

As the Biodiesel program is still in it's infancy several challenges can be defined including:

- The availability of feedstock in adequate quantity and quality. See below fro a discussion on feedstocks.
- Setting up the logistics chain for new product. Biodiesel requires specific infrastructure for transport and storage (See also part 2).
- The distance between producing plants and final consumer market can be a challenge

[11] Soybean biodiesel is excluded (Alameida et al., 2008).

- Product quality and biodiesel stability
- Finding uses for products (Glycerin, (toxic) protein cake)

3.4 Biodiesel feedstocks

Biodiesel feedstocks in Brazil have been evaluated and discussed in several publications (Alameida *et al.*, 2008; Rodrigues and Macedo, 2006; Kaltner *et al.*, 2005; MAPA, 2006). In order to assess biodiesel feedstocks options it is important to differentiate between oils and fats as a main product, as a co-product or a by-product (or even a waste product). In case an oil or fat is a by-product a change in market price will not increase the production of the main product. At most it will lead to higher efforts to extract the oil or fat by product. Examples are the conversion of fee fatty acids which has been a waste product in palm oil processing at Agropalma (see part 4) or the recovery of waste frying oil for conversion to biodiesel. Generally this development seems to have a favorable environmental profile under current EU sustainability criteria as most or all environmental impacts are allocated to the main product. Little information can be found on the possibility to increase the oil/fat production from by-products and wastes in Brazil. It seems quite likely that many other by-products and wastes in Brazil can be recovered and oil or fats can be extracted if prices are high enough and stable enough to make investments and logistic costs worth wile. Further on a few of these options are discussed.

Many oil crops are essentially dual purpose crops which produce both oil and a co-product. Soy and rape are examples where oil and protein are co-products. The oil production per ha is lower than of single purpose oil crops but the production costs can be carried by both products. Obviously an increase in oil demand due to biodiesel demand without a simultaneous increase in protein demand will make the oil less attractive compared to single purpose oil crops. At the same time an increased demend for protein would make soy oil a more attractive oil for biodiesel.

Other relevant aspects are suitability of the oil or fat for conversion into biodiesel (see part 2 of this report) and alternative uses which often command a better price than utilization for biodiesel. Below we give an overview of the most important sources and discuss the advantages and draw backs of each Brazilian biodiesel feedstocks option:

Sources of oil/fat as a by-product
Animal fats i.e. tallow
Tallow is a by-product of beef processing. As the worlds largest beef producer with almost 200 million heads Brazil produces some 1 million tons per year. Alternative uses include soap production. It has been reported that due to increased soy oil prices in

recent years some biodiesel plants that planned to produce biodiesel from soy oil have switched to tallow as a feedstock. As a results the tallow price has increased (Alameida *et al.*, 2008). With conventional biodiesel production technology tallow can only be mixed to a small degree into biodiesel if current EU biodiesel norms are to be observed. Overall tallow should be considered as only a minor option for biodiesel production with less relevance for export.

Cotton seed

Cotton seed oil is a by-product of cotton fibre production which exists in all parts of Brazil except the Amazon region. The oil content of the seed is between 13 and 32%, yielding 270 to 450 kg oil per ha plus a protein rich cake which is used as animal feed. The relatively low price may make it quite an attractive biodiesel option (Rodrigues and de Macedo Beltrão, 2006). With a production of 315 million liters (da Silva, 2007) based on cotton production in 2005 it is the second largest option (far) behind soy. Varieties and production systems with up to 1000 l of oil production per ha may be developed (Rodrigues and Macedo, 2006). Still, as with other co-products increased demand will increase price but will not rise production in the short term.

Sources of oil/fat as a co-product

Soybean (*Glycine max*)

Soybean is by far the largest oil producing crop in Brazil occupying some 22 million ha in all areas of Brazil and producing 60 million tons in 2006 (Rodrigues and de Macedo Beltrão, 2006). Soybeans can be processed into 20% oil and 80% high protein cake. Soybean production was 58.9 million tons on x million ha in 2007/2008 of which almost 29.8 million tons were processed in Brazil into 5,7 million tons of oil and 22,8 million tons of meal (ABIOVE, 2008). Overall soy is responsible for almost 80% of vegetable oil production in Brazil.

As soy produces 5x more high protein meal than oil, the soy oil production has been mostly a function of protein demand. Generally soy oil has been seen as a by-product with a low price in Brazil. Biodiesel production may provide an outlet for 'surplus' oil making soybean production and processing in Brazil more attractive (Kaltner *et al.*, 2005). For an in depth analysis of soy production and especially the environmental impact see part 3 of this report.

Rape/canola (*Brassica napus*)

Rapeseed is a small crop in Brazil which can only be grown in southern areas. With an oil content of more than 40% and 500 to 1000 l of oil production per ha plus a protein cake it is more of an oil crop and less a protein crop than soy. Rape oil has good biodiesel characteristics under European conditions. Furthermore European biodiesel specifications have been designed with rape oil in mind making it the ideal biodiesel option in Europe.

Though southern regions in Brazil are suitable for rape production and new varieties could be developed that expand the rape area, the crop should not be considered an important option for Brazil at this moment.

Oil crops

Oil palm (*Elaeis guineensis*)

Elbersen (2008) reviewed palm oil production for biodiesel in Brazil (see Part 4). In short, African oil palm is the most productive oil crop available in Brazil with 4000 to 6000 liter per ha per year. Brazil produces only 0,5% of palm oil in the world, mainly in a few areas in the state of Para and near the Northeast Coast and actually is a net importer of palm oil. Still, it has the largest land area potentially available for palm oil production. Estimates vary widely from 70 million ha (Rodrigues and Macedo, 2006); 20 million ha as mentioned by Kaltner *et al.* (2005) to 7 million ha by Gazzoni (2007). Much of the suitable land is covered by rain forest and should not be a sustainable or Greenhouse Gas positive option. Still, for degraded areas it is seen as very promising. Kaltner *et al.* (2005) reports that some 3 million ha of degraded /altered land is available in the short run where basic infrastructure is available for palm oil production. In this respect it is important to note that the definition of degraded land is not clear.

Oil palm is considered one of the most promising options in Brazil which is generally viewed favorably from an environmental and social perspective as we observed during a visit to the palm growing areas in Para and discussions with NGOs. Contrary to cattle and soy farming oil palm is not associated with deforestation and the large scale plantation activities generally appear to comply with the complicated environmental regulations that among other stipulate that only a part of the landholding has be used for plantation while the rest has to be protected (see part 3 and part 4 for further explanation). Palm oil requires large scale investments and the need for processing of palm oil fruits within 24 hours. This makes that palm oil plantations have to be at least 1000 ha is size to be economically viable. A lag time of at least 4 to 6 years between starting up of a project and the start of biodiesel delivery is expected because of the need to set up an infrastructure and the time between planting and first oil yield. On top of this there is only limited agronomic knowledge about oil palm in Brazil which also may limit the rate of implementation. To supply the 2.4 billion liter of biodiesel in 2013 as mandated in Brazil it would require 600.000 ha of oil palm compared to 4 million ha soy. As reviewed in part 4 a number of factors will have to be dealt with in order for the palm oil to become a really viable option for biodiesel export to the EU. Still, oil palm should be considered one of the most important options for large scale biodiesel production in Brazil for export to the EU in due time.

Castor (*Ricinus communis*)
Castor is an oil crop producing seeds with a toxic oil that has good quality characteristics for a number of chemical applications. In recent years castor oil has been promoted as a very promising feedstock for biodiesel in the poor and dry north east region of Brazil, where it should be an important option for small and poor family farms providing the desired social impact of the biodiesel program (see above). Oil yields are between 0,5 to 1 ton per ha. The press cake (by-product) is not used for feed and can (only) be applied as fertilizer. In 2005 168.000 ton castor oil was produced in Brazil (Alameida *et al.*, 2008). Experience in recent years has shown that production under dry conditions is low and unstable. On top of this castor biodiesel (transesterification) does not comply with biodiesel standards (see part 2 of this report) making it unsuitable for higher mixtures. In Brazil the cost of castor oil biodiesel is twice as high compared to biodiesel based on soy or palm oil (Kaltner *et al.*, 2005). It was concluded that castor oil has the highest production cost and market price (the oil is much for chemical industry purposes) making it only an option for biodiesel if subsidies are available (Kaltner *et al.*, 2005; Alameida *et al.*, 2008). Most of the castor oil produced for biodiesel in being exported for other purposes. Together with the low quality for conventional biodiesel production castor appears not to be a viable biodiesel export option.

Sunflower (*Helianthus annus*)
Sunflower is a very small crop in Brazil even though there is a considerable potential area for the crop in Brazil mostly in the southern half of Brazil (Rodrigues and de Macedo Beltrão, 2006). In 2005 only 23.000 tons were produced in Brazil with 630 liter of oil per ha (Alameida *et al.*, 2008). Though sunflower oil can be used for biodiesel production it does not fit the current EU biodiesel standards. Therefore it can only be mixed to a low degree into biodiesel.

Jatropha (*Jatropha curcas*)
Is a perennial shrub related to Castor that produces beans with a high (30 to 45%) oil content that is toxic and cannot be used for food or feed. Jatropha is essentially new crop for which still much development is needed such as adapted varieties, agronomic practices and processing options (Jongschaap *et al.*, 2007). The plant is considered a promising crop especially under low input and dry conditions. Yields vary with water availability and other inputs and vary between less than 500 L to more than 2000 L oil per ha (Jongschaap *et al.*, 2007). Jatropha seeds can be stored for a long time between harvesting and processing making it possible to produce the crop with little infrastructure requirements.

3.5 Sustainability

Sustainability issues have a different focus in the Netherlands and EU compared to Brazil. The EU and especially the Netherlands emphasize the role biofuels need to play in security of supply and especially in reduction of GHG emissions compared to fossil fuel use. In Brazil the focus is much more on socio-economic issues. Such as the role biofuels and biodiesel in particular can play in social development in rural areas or the substitution of imports, air quality etc. It is our impression that reduction of GHG emissions from the use of biodiesel are seen as a given and an opportunity of carbon credit trade. Still, studies on the GHG balance of these new biodiesel production chains are scarce (see also part 3 of this report).

As far as we and others (Dam *et al.*, 2008) have been able to assess no certification system for biomass or biofuels exists in Brazil at the moment. However Brazilian parties are involved in so called Round table initiatives which develop sustainability principles and criteria for palm oil (RSPO), soy (RTRS) and biofuels (RSB). At the national Brazilian level the 'Social Fuel Certificate' as discussed above is part of the biodiesel program which defines conditions for receiving federal tax exemptions and favorable loans. In order to receive the certificate, an industrial producer must purchase feedstock from family farmers and enter into a legally binding agreement with them to establish specific income levels and guarantee technical assistance and training (Ministry of Mines and Energy, 2006).

As the sustainability issues have become an important part of the license to produce biofuels for EU biofuel providers, Brazilian partners at the upstream of the production chain will be asked first to report on sustainability performance especially with respect to GHG performance. Later when certification systems and methods are in place meeting criteria could be a source of extra income as it is already for some commodities (see Elbersen 2008). Adaptation of production systems to meet the criteria will be a logical step.

At the same time issues are complicated and the proliferation of different certification systems may easily obstruct necessary development of a fair market in sustainable fuels. Coordinated action at higher levels to develop coherent sustainability systems is probably needed. In this respect it would be logical that criteria and assessment systems are developed jointly between The Netherlands (or EU) and Brazil taking into account the respective sustainability needs and concerns. Especially dealing with indirect effects will be a difficult issue.

4 Conclusions

Indirectly Brazil probably is already an important supplier of biodiesel (or feedstocks) through re-export of soy biodiesel from the US to Europe. Still this does not seem to be the way of the future. Direct Brazil/NL trade of biodiesel or feedstocks should be the goal for the (near) future.

Still, for the coming years Brazil will be developing its own biodiesel infrastructure and market which will require much of the resources. Apart from soy most of the biodiesel production options require some time to develop even if, as with Jatropha, progress is made fast.

Though at this moment there are no specific demands on the sustainability of biodiesel (in the EU) it is quite clear that public pressure is already relevant for biodiesel distributors. It is also very clear that sustainability will be key to further development of biodiesel in the EU. Future biofuel mixing requirements will not be possible without assurances of a sustainable supply.

We argue that the official sustainability demands will focus heavily on GHG performance of biofuel as this is a primary driver for the existence of biofuels in the EU. Furthermore it is also a demand that can be set under WTO and EU trade regulations. GHG performance can in principle be quantified in an objective way, though much needs to be assessed and developed. Methods and cost effective certification (or other systems) will have to be implemented and producers may have to adapt production systems in order to improve GHG impact.

Challenges lie in agreeing on methods for GHG assessment especially for indirect effects (see part 3).

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Part 2. Technical issues: how can Brazilian biodiesel comply with EU quality demands – now and in the future?

Rolf Blaauw
Wolter Elbersen

1 Introduction

Standardization is one of the key issues in the development of new products and markets. For the producers and distributors of biodiesel, standards are a vital necessity. Legislators and authorities need approved standards for the evaluation of safety and environmental risks. The development of engines, vehicles and equipment is based on the properties of the fuel, hence the range of the fuel parameters must be limited.
The development of a new standard is a complex task. Many stakeholders are involved and many factors have to be considered, such as available feedstocks, emission legislation, engine and after-treatment technology, political and social issues, etcetera. As a consequence, standards for a certain product or technology are often not the same in different parts of the world. This is also true for the current European and Brazilian biodiesel standards.

1.1 Objective

The objective of this study is to find out which technical barriers have to be overcome before Brazilian biodiesel can enter the EU market and comply to EU quality standards. Research questions that will be answered are:

- *Does Brazilian biodiesel currently comply to EU quality standards, and if not, why not?*
- *How can Brazilian biodiesel comply to current and future EU standards?*

Trade issues are not part of this report.

1.2 Approach

Information was gathered by literature study, meetings in Brazil and the Netherlands, and participation in the International Conference on Biofuel Standards held in February 2007 in Brussels.

2 Biodiesel fuel quality

2.1 Biodiesel

Biodiesel is a diesel fuel substitute that can be produced by chemical reaction of renewable lipid sources such as vegetable oils, animal fats and recycled cooking oils, with an excess of a simple alcohol such as methanol or ethanol. The reaction is performed in the presence of a catalyst and yields glycerin and so-called *fatty acid monoalkyl esters* abbreviated FAME in the case of methanol as the reacting alcohol, and FAEE in case of ethanol. In most countries, where methanol is the cheapest alcohol, biodiesel is synonymous with FAME, and many current standards are designed in such a fashion that only methyl esters can be used as biodiesel if the standards are observed correctly.

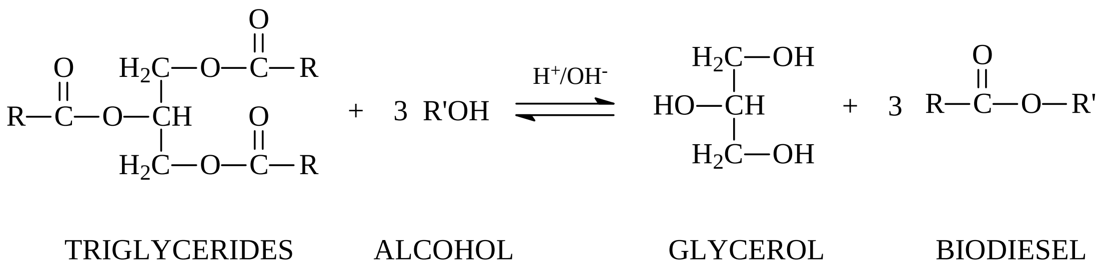

Figure 2.1. The transesterification reaction. R is a mixture of various hydrocarbon chains. R' is usually CH_3 (R'OH = methanol) but can also be CH_3CH_2 (R'OH = ethanol).

The major reason why vegetable oils and animal fats are transesterified to monoalkyl esters is that the kinematic viscosity of the biodiesel is much closer to that of petrodiesel. The high viscosity of untransesterified oils and fats leads to operational problems in the diesel engine such as deposits on various engine parts.
The chemical structure of biodiesel resembles that of compounds present in petrodiesel, in the sense that both biodiesel and petrodiesel have long hydrocarbon chains. This also translates to similar combustion behaviour, and is therefore the major reason why biodiesel can be used as an alternative fuel for diesel engines.

2.2 Factors affecting the fuel quality of biodiesel

Advances in engine technology and reduction of exhaust emissions cannot be accomplished if the fuel does not comply to certain minimum quality requirements. Like petrodiesel, biodiesel has to have a certain set of properties that fall within a limited range in order to be suitable as a transportation fuel. The most important factors that determine the properties and quality of biodiesel are:

- type of feedstock, *e.g.* soybean versus rapeseed oil
- type of alcohol, *e.g*. methanol versus ethanol
- purity of the feedstock
- the biodiesel production process
- fuel additives
- storage and transportation conditions

2.2.1 Type of feedstock

Although the chemical structure of triglycerides from various sources at first glance may look very similar, there are small differences that cause the properties of the different vegetable oils and animal fats to be quite different. Features such as the carbon length of the fatty acid chain, the amount of 'unsaturation' (*i.e.* the amount of carbon-carbon double bonds), the amounts in which the different fatty acid chains are present in the oil or fat, all influence the final properties. A biodiesel made from palm oil, for instance, will have certain fuel properties that are very different from a biodiesel made from rapeseed oil. So, whereas palm oil methyl ester is a good biofuel in tropical climates, it would cause engine problems in colder climates due to its higher cloud point (*i.e.* the temperature at which wax crystals first appear during cooling of the fuel).

2.2.2 Type of alcohol

Generally this factor is overlooked, since almost everywhere methanol is used for biodiesel production. Here it is an important issue. The Brazilian bioethanol market is very large, and ethanol is only slightly more expensive there than methanol. When the feedstock quality and process conditions are right, both alcohols yield good biodiesels of comparable quality. Ethyl esters have slightly better combustion properties, and also better 'cold flow' properties (*i.e.* better fuel behaviour at lower operating temperatures) than the corresponding methyl esters. The viscosity of ethyl esters is generally higher due to their slightly higher molar mass.

2.2.3 Purity of the feedstock

The higher the content of triglycerides in the oil or fat, the higher the amount of monoalkyl esters after transesterification, and so the better the quality of the resulting biodiesel. That's the reason why most biodiesel factories still use refined vegetable oils, despite their somewhat higher costs. These are virtually free of solids and other impurities naturally present in oils and fats which, when ending up in the final biodiesel product, would lead to deterioration of engine parts and increased exhaust emissions.

2.2.4 The biodiesel production process

The conditions and chemicals used during biodiesel production, including biodiesel separation and purification steps, are a very important factor in determining the quality of the final biodiesel product. The most important issue is the completeness of the transesterification reaction, which should be as close to 100% as possible. Adequate separation of the glycerol co-product and removal of excess alcohol, catalyst, and other by-products is vital for obtaining a good quality biodiesel.

2.2.5 Fuel additives

It is common practice to optimise the properties of transportation fuels by using additives. In today's sophisticated diesel engines, a diesel fuel without additives would almost be considered as a bad fuel. To enable smooth engine operation at cold temperatures, diesel is provided with so-called 'cold flow improvers'. Similar additives are added to 'winter grade' biodiesel. It must be emphasised that a biodiesel of poor quality can hardly ever be transformed into an excellent fuel just by using additives.

2.2.6 Storage and transportation conditions

During storage and transportation of biodiesel, contact with water and oxygen should be kept at a minimum. Biodiesel takes up as much as 30 times more water than petrodiesel. During engine operation, water may contribute to corrosion of engine parts. It may also lead to microbial growth in the fuel. Oxidation of biodiesel by oxygen (a process similar to the 'drying' of oil paints) leads to the formation of acids and to higher viscosity of the fuel. Antioxidants are added to suppress oxidation and increase storage stability.

It is clear from the above that biodiesel quality control is crucial in ensuring good engine operability and maintenance. Quality standards for biodiesel have been developed to aid producers, traders, engine manufacturers and other stakeholders in achieving technological, economical and ecological goals. Quality standards are the topic of the next chapter.

3 Fuel quality standards

3.1 Introduction

Standards are technical specifications for products, processes or services. They should be approved by all parties involved and should reflect the current state of the art. Standardization diminishes trade barriers, promotes safety, allows interoperability of products, systems and services, and promotes common technical understanding. Standards are drawn up in independent institutes of standardization. In principle, standards are not binding, although they can become legally binding on a national or international level.

3.1.1 The European Standardization Committee (CEN)

In Europe, the organization responsible for developing European standards is called CEN (Comité Européen de Normalisation). CEN is a system of formal processes to produce standards. The responsibilities are shared principally between:

- Thirty *National Members* and the representative expertise they assemble from each country. These members vote for and implement European Standards (ENs). CEN's National Members are the National Standards Organizations of 30 European countries. There is only one member per country. They have voting rights in the General Assembly and Administrative Board of CEN and provide delegations to the Technical Board which defines the work program. It is the responsibility of the CEN National Members to implement European Standards as national standards, to distribute and sell them and to withdraw any conflicting national standards
- Seven *Associate Members* and two *Counselors*. The Associate Members are broad-based European organizations, representing particular sectors of industry as well as consumers, environmentalists, workers, and small and medium-sized enterprises. Counselors participate in the CEN General Assembly. They also attend the Administrative Board when policy issues are being discussed. Counselors are from European institutions. At present there are two Counselors: the European Commission and the EFTA Secretariat (EFTA = European Free Trade Association)
- The *CEN Management Centre*. The CEN Management Centre (CMC) assists the Secretary General in carrying out his statutory functions. Functions include maintenance of CEN's procedures, assistance for Technical Committees, and budget management.

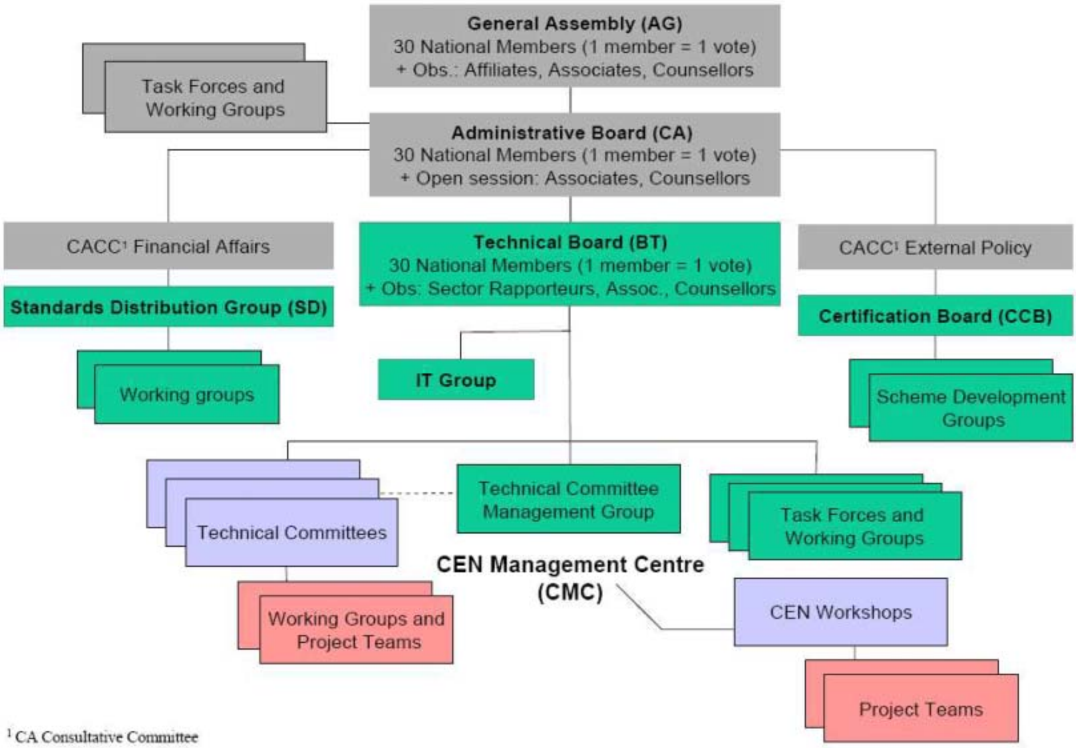

Figure 2.2. Organization of the main committees within the CEN System.

3.2 Current diesel and biodiesel standards in the EU and Brazil

3.2.1 European biodiesel standards

In 1997, due to the growing production of biodiesel in Europe during the 1990s, the European Commission gave a mandate (M/245) to CEN '*for the elaboration and adoption of standards concerning minimum requirement specification including test methods for fatty acid methyl ester (FAME) as fuel for diesel engines and for space heating*'. Working groups of two existing Technical Committees –TC19 and TC307– were given the task to develop a European standard and test methods for biodiesel as an automotive fuel, and another standard for biodiesel as a heating fuel. The mandate also included a modification of petrodiesel standard EN 590 in order to allow a maximum of 5% biodiesel as a blend fuel. Existing national standards from *e.g.* Austria, Germany and France were taken as the basis for the development. The difficulty was that, whereas the European Commission aimed at standards for FAME in general, almost all data available was based on only *rapeseed methyl ester*. This had two consequences: (1) the new biodiesel standards for B100 (*i.e.* pure FAME) put quite strict limitations on the various properties listed in the standards, which in essence meant that only rapeseed methyl ester was acceptable as biodiesel, and (2) biodiesel used for blending (up to 5%) with petrodiesel should have the

same (high) quality as defined in the standard for B100. The blend has to comply to diesel standard EN 590.
Thus, two new standards were developed and one existing standard was modified:

- EN 14213: Heating fuels – Fatty acid methyl esters (FAME) – Requirements and test methods. July 2003. Intended both as a neat fuel and as a blending component. Blends have to comply to existing national standards, since there is no European standard for (fossil) heating oil.
- EN 14214: Automotive fuels – Fatty acid methyl esters (FAME) for diesel engines – Requirements and test methods. July 2003. Intended both as a neat fuel and as a blending component. Specifications are shown in Table 2.1.
- EN 590: Automotive fuels. Diesel. Requirements and test methods. Now contains an amendment allowing a maximum of 5% biodiesel complying to EN 14214.

The final standards were published shortly after the European Parliament on the 8th of May 2003 issued Directive 2003/30/EC '*on the promotion of the use of biofuels or other renewable fuels for transport*'.

Table 2.1. European biodiesel standard for automotive fuels EN 14214.

Property	Limit	Unit	Test method
Ester content	≥ 96.5	% (m/m)	EN 14103
Density at 15°C	860–900	kg/m^3	EN ISO 3675; EN ISO 12185
Kinematic viscosity at 40°C	3.5–5.0	mm^2/s	EN ISO 3104; ISO 3105
Flash point	≥ 120	°C	EN ISO 3679
Sulfur content	≤ 10.0	mg/kg	EN ISO 20846; EN ISO 20884
Carbon residue (10% dist. residue)	≤ 0.30	% (m/m)	EN ISO 10370
Cetane number	≥ 51	–	EN ISO 5165
Cold Filter Plugging Point	*a*	°C	EN 116
Sulfated ash	≤ 0.02	% (m/m)	ISO 3987
Water content	≤ 500	mg/kg	EN ISO 12937
Total contaminants	≤ 24	mg/kg	EN 12662
Copper strip corrosion (3 hours at 50°C)	Class 1	–	EN ISO 2160
Oxidative stability at 110°C	≥ 6.0	hour	EN 14112
Acid number	≤ 0.50	mg KOH/g	EN 14104

Property	Limit	Unit	Test method
Iodine number	≤ 120	g iodine/100 g	EN 14111
Linolenic acid content	≤ 12	% (m/m)	EN 14103
FAME with ≥ 4 C=C	≤ 1	% (m/m)	–
Methanol content	≤ 0.20	% (m/m)	EN 14110
Monoglyceride content	≤ 0.80	% (m/m)	EN 14105
Diglyceride content	≤ 0,20	% (m/m)	EN 14105
Triglyceride content	≤ 0.20	% (m/m)	EN 14105
Free glycerol	≤ 0.02	% (m/m)	EN 14105; EN 14106
Total glycerol	≤ 0.25	% (m/m)	EN 14105
Alkali metals (Na + K)	≤ 5.0	mg/kg	EN 14108; EN 14109
Earth alkali metals (Ca + Mg)	≤ 5.0	mg/kg	EN 14538
Phosphorus content	≤ 10.0	mg/kg	EN 14107

a. Selected by national standardizing committees. For e.g. Germany, the requirements are –20°C for winter grade, –10°C for spring and autumn grades, and 0°C for summer grade.

3.2.2 Brazilian biodiesel standards

Initiated by the Brazilian government in 2002 and officially launched by the end of 2004, the National Program of Production and Use of Biodiesel (PNPB) aims at adding biodiesel in the Brazilian energy matrix. With the purpose of creating a market for biodiesel, a law (11.097/2005) that requires the addition of biodiesel into diesel (2% in 2008, and 5% in 2013) was passed. Besides economic and environmental drivers the Brazilian biodiesel program has a strong socio-economic element. The Brazilian government actively wants to engage small farmers and producers of the poorest regions in the biodiesel value chain. This is being achieved by means of tax incentives granted to firms that purchase oil-producing crops grown by small farmers. More specifically, biodiesel producers that acquire raw materials from family farmers, anywhere in Brazil, are eligible to reduction of up to 68% in federal taxes. If these purchases are made from family-based producers of palm oil in the North Region, or of castor oil in the Northeast and in the Semi-Arid Region, the reduction may reach 100%. If the raw materials and regions are the same, but producers are not family farmers, then the maximum reduction is 31%. In order to qualify for these tax benefits, biodiesel producers have to hold a certificate: the Social Fuel Stamp. In order to obtain this certificate, biodiesel manufacturers have to meet certain requirements, such as minimal purchase amounts of raw materials, and entering into contracts with family farmers for establishing deadlines, conditions of delivery and prices.

The first Brazilian specification for biodiesel was released on September 15th, 2003, by the federal regulatory agency for petroleum derivatives, Agência Nacional do Petróleo (ANP). This standard, ANP 255, was created to support the preliminary activities of the National Biodiesel Program by ensuring good fuel properties for biodiesel blends up to 20% in diesel (B20). Standard ANP 255 defines biodiesel as monoalkyl esters of long chain fatty acids derived from vegetable oils or animal fats. Similar to the biodiesel standard of the United States of America (ASTM D 6751), no differentiation is made between biodiesel derived from methanol or ethanol.
Defining the specifications for ANP 255 was very complicated, since a too conservative set of requirements would exclude important oil crops from poorer regions that are less common for biodiesel production, such as castor oil. As a consequence, provisional ANP 255 is less strict on certain quality aspects than *e.g.* European standard EN 14214. On the other hand, ANP 255 is intended for private fleets using diesel blends up to B20, whereas EN 14214 is also for B100, *i.e.* pure biodiesel.
Most of the underlying test methods of ANP 255 are taken from the European and American standard test methods. However, for some properties Brazilian methods (NBR standards) proposed by the Brazilian Association of Technical Methods (ABNT) can be used. Note that some of the test methods mentioned in the European and American biodiesel standards are only suitable for methyl esters and not for ethyl esters. The specifications according to ANP 255 are shown in Table 2.2.

Table 2.2. Brazilian provisional biodiesel standard ANP 255 (2003).

Property	Limit	Unit	Test method[c]
Aspect (visual)	LII[a]	–	–
Density at 20°C	ANP 310[b]	kg/m^3	NBR 7148/14065; D 1298/4052
Kinematic viscosity at 40°C	ANP 310[b]	mm^2/s	NBR 10441; D 445; EN ISO 3104
Flash point	≥ 100	°C	NBR 14598; D 93; ISO/CD 3679
Sulfur content	≤ 0.001	% (m/m)	D 5453; EN ISO 14596
Carbon residue (after 100% dist.)	≤ 0.05	% (m/m)	D 4530/189; EN ISO 10370
Cetane number	≥ 45	–	D 613; EN ISO 5165
Cold Filter Plugging Point	ANP 310[b]	°C	NBR 14747; D 6371
Sulfated ash	≤ 0.020	% (m/m)	NBR 9842; D 874; ISO 3987
Water and sediments	≤ 0.050	% (v/v)	D 2709
Distillation recovery, 95%	≤ 360	°C	D 1160
Copper strip corrosion (3 hours at 50°C)	Class 1	–	NBR 14359; D 130; EN ISO 2160
Oxidative stability at 110°C	≥ 6	hour	EN 14112

Property	Limit	Unit	Test method[c]
Acid number	≤ 0.80	mg KOH/g	NBR 14448; D 664; EN 14104
Iodine number	Take note	g iodine/100 g	EN 14111
Alcohol content	≤ 0.50	% (m/m)	EN 14110
Monoglyceride content	≤ 1.00	% (m/m)	D 6584; EN 14105
Diglyceride content	≤ 0.25	% (m/m)	D 6584; EN 14105
Triglyceride content	≤ 0.25	% (m/m)	D 6584; EN 14105
Free glycerol	≤ 0.02	% (m/m)	D 6584; EN 14105; EN 14106
Total glycerol	≤ 0.38	% (m/m)	D 6584; EN 14105
Alkali metals (Na + K)	≤ 10	mg/kg	EN 14108; EN 14109
Phosphorus content	≤ 10	mg/kg	D 4951; EN 14107

a. 'Límpido e isento de impurezas', i.e. clear and free from impurities (visual).

b. Value of the final blend should comply to ANP 310 (the Brazilian diesel standard).

c. Brazilian ABNT NBR, American ASTM D, European EN and international ISO standards.

In November 2004 another standard, ANP 42, was published. ANP 42 is the first Brazilian standard that authorizes the commercial use of biodiesel as a 2% blend in diesel. Use of B2 will be mandatory in 2008. The specification contains quite some '*take note*' requirements, for several reasons. First, ANP 42 is for biodiesel/diesel blends, whereas European standard EN 14214 is also for use as neat biofuels (B100). Particularly, fuel properties of a fuel containing only 2% biodiesel (B2) will be dominated by the properties of the petrodiesel. Second, the validity of some of the European test methods (*e.g.* EN 14104, 14105 and 14110) for biodiesel prepared from certain crop oils such as castor oil has to be checked. Similarly, some of the European test methods are not suitable for ethyl esters, and modified methods have to be developed.

Table 2.3. Brazilian biodiesel standard ANP 42 (2004).

Property	Limit	Unit	Test method[c]
Aspect (visual)	LII[a]	–	–
Ester content	Take note	% (m/m)	EN 14103
Density at 20°C	ANP 310[b]	kg/m^3	NBR 7148/14065; D 1298/4052
Kinematic viscosity at 40°C	ANP 310[b]	mm^2/s	NBR 10441; D 445; EN ISO 3104
Flash point	≥ 100	°C	NBR 14598; D 93; EN ISO 3679

Property	Limit	Unit	Test method[c]
Sulfur content	Take note	% (m/m)	D 4294/5453; EN ISO 14596
Carbon residue (after 100% dist.)	≤ 0.10	% (m/m)	D 4530/189; EN ISO 10370
Cetane number	Take note	–	D 613; EN ISO 5165
Cold Filter Plugging Point	ANP 310[b]	°C	NBR 14747; D 6371
Sulfated ash	≤ 0.020	% (m/m)	NBR 9842; D 874; ISO 3987
Water and sediments	≤ 0.050	% (v/v)	D 2709
Total contaminants	Take note	mg/kg	EN 12662
Distillation recovery, 90%	≤ 360	°C	D 1160
Copper strip corrosion (3 hours at 50°C)	Class 1	–	NBR 14359; D 130; EN ISO 2160
Oxidative stability at 110°C	≥ 6	hour	EN 14112
Acid number	≤ 0.80	mg KOH/g	NBR 14448; D 664; EN 14104
Iodine number	Take note	g iodine/100 g	EN 14111
Alcohol content	≤ 0.5	% (m/m)	EN 14110
Monoglyceride content	Take note	% (m/m)	D 6584; EN 14105
Diglyceride content	Take note	% (m/m)	D 6584; EN 14105
Triglyceride content	Take note	% (m/m)	D 6584; EN 14105
Free glycerol	≤ 0.02	% (m/m)	D 6584; EN 14105; EN 14106
Total glycerol	≤ 0.38	% (m/m)	D 6584; EN 14105
Alkali metals (Na + K)	≤ 10	mg/kg	EN 14108; EN 14109
Earth alkali metals (Ca + Mg)	Take note	mg/kg	EN 14538
Phosphorus content	Take note	mg/kg	D 4951; EN 14107

a. 'Límpido e isento de impurezas', *i.e.* clear and free from impurities (visual).

b. Value of the final blend should comply to ANP 310 (the Brazilian diesel standard).

c. Brazilian ABNT NBR, American ASTM D, European EN and international ISO standards.

3.3 Compliance of Brazilian biodiesel to EN 14214

It is clear that existing biodiesel standards such as EN 14214 and ANP 42 have been developed with the internal markets of Europe and Brazil, respectively, in mind. The differences between the two standards reflect the different geographical, political, social, economical and ecological situation in these regions.

3.3.1 Factors explaining the differences between Brazilian and European biodiesel standards

Brazil and Europe are different in many respects. Some of the factors that are reflected in their current biodiesel quality standards are:

- *Climate*. Some European countries put quite severe demands on the cold flow properties of diesel and biodiesel, due to the cold winters with temperatures well below 0°C. In order to prevent cold-start engine failure, the so-called Cold Filter Plugging Point (CFPP) for winter grade biodiesel according to EN 14214 is set at –20°C in countries like Germany and the Netherlands, and can even be –44°C in the most northern countries. In Brazil, the CFPP of the final blend of biodiesel (e.g. B2) should be as defined in the Brazilian diesel specification ANP 310. The CFPP requirements for diesel and biodiesel blends in Brazil vary per region, but on a whole are less strict than in Europe.
- *Crops*. In Europe, rape is by far the most important oil crop, followed by sunflower and olive. Consequently, most European biodiesel is rapeseed methyl ester (RME). On the other hand, Brazil hardly has any rapeseed. Most Brazilian biodiesel is currently made from soybean oil. But soy is not grown all over the country, and particularly in the poorer regions in the North and Northeast other oil crops are important, such as castor ('mamona') and different kinds of palm. Due to the strong socio-economic drivers of the Brazilian Biodiesel Plan, much effort is put into creating biodiesel quality standards that allow these less common feedstocks to be used as biodiesel. This also means that existing standard test methods have to be adapted or even new methods developed in order to make them usable for crops like castor. This is one of the reasons for some of the 'take note' requirements of the current Brazilian biodiesel specification ANP 42.
- *Cars*. Contrary to Brazil, European passenger cars are allowed to have diesel engines. In fact, total gasoline and diesel consumption are about equal in the EU, and the share of diesel cars is expected to grow further. The observed shift to diesel cars in most European countries stems from the fact that diesel fuel is more efficient in economic terms (approx. 2 litres per 100 km) and cheaper than gasoline due to lower taxes in most European countries, thereby offsetting the higher purchase costs of diesel cars and the slightly higher production costs of diesel fuel. From an environmental point of view, a diesel engine emits approx. 30% less CO_2 than its gasoline counterpart, thus diesel technology is seen as a major device for meeting the Kyoto commitments. The reverse side of the coin is the probably harmful diesel exhaust, which poses a serious air pollution problem despite technological advances in emission control. This has led to more stringent emission restrictions in Europe compared to Brazil.
- *Costs.* Quality control for biodiesel requires a considerable investment in testing equipment. For small scale local production of biodiesel to be a success, such investments should be kept as low as possible. This means that the quality standards

should not be unnecessarily restrictive by containing procedures that are somewhat repetitive in providing similar conclusions. An example is the inclusion in EN 14214 of both methanol content and flash point; if the flash point is above 120°C, as required, then this means that methanol content (or alcohol content in general) will be sufficiently low to allow safe handling. In other words, a too high methanol content will inevitably result in a too low flashpoint, so it is unnecessary to include both parameters in the biodiesel specification. Currently, the Brazilian standard ANP 42 also requires both flash point and alcohol content to be measured.

3.3.2 Does Brazilian biodiesel currently comply to EN 14214?

The current European quality standard EN 14214 is strongly based on the properties of rapeseed methyl ester (RME). Since Brazilian biodiesel is based on other crops, it may be difficult to comply to all requirements of EN 14214, particularly when the biodiesel is based on one crop (*e.g.* soybean methyl ester). Table 2.4 lists a number of biodiesel properties and shows whether biodiesel from different crops complies to the required values.

Table 2.4. Critical properties of different biodiesel types with regard to EN 14214.

Biodiesel type	Compliance	Critical properties	Other drawbacks
Soybean ME	No	Iodine value	Oxidation stability, CFPP
Castor ME	No	Viscosity; cetane number; density	CFPP
Palm ME	No	CFPP	
Jatropha ME	No	CFPP	
Rapeseed ME	Yes	-	-

It is clear from Table 2.4 that it is very hard for biodiesels based on one-crop to meet all requirements of the European standard. This is particularly so for the stricter CFPP requirements during winter, autumn and spring. There may, however, be a limited number of options to obtain a biodiesel that *does* comply:

- Soybean methyl ester (SME) may be blended with a less unsaturated biodiesel (*e.g.* from palm) to yield a blend that has a lower iodine value and better oxidation stability.
- Partial hydrogenation of soybean oil or SME will reduce unsaturation, and thus reduce iodine value and increase oxidation stability. However, the extra process step will add to the cost of biodiesel.
- Additives such as antioxidants may be –and are– used to increase oxidation stability (although iodine value is not changed). Cold flow improvers may also be used, but

diesel blenders and distributors usually demand that the biodiesel is free of such additives, since these may negatively affect the performance of other diesel fuel additives.

Currently, there is discussion within the EU standardizing organisations on raising the iodine value in EN 14214 from 120 to 130. This would allow the use of neat soybean methyl ester, provided that the oxidation stability is enhanced by adding antioxidants.

4 Developments in biodiesel technologies and standards

4.1 Next generation biofuels technologies

Biodiesel from vegetable oils and bioethanol from starch and sugar are called *conventional* biofuels. Many use the term '*first generation*' biofuels, to distinguish them from upcoming biofuels technologies of the '*second generation*' that are currently in a research and development stage. These next generation biofuels are considered better fuels than conventional biodiesel and bioethanol for a number of reasons. Firstly, they are not made from starch, sugars, vegetable oils or proteins, *i.e*. the parts of the crop that are used for food and feed production. Instead, the so-called lignocellulosic 'waste' of food crops and other non-food biomass such as wood and grass are the raw materials. Secondly, there is much more lignocellulosic biomass available than vegetable oils, starch and sugar, making it easier to reach the ambitious targets of political leaders regarding the (future) share of biofuels in our energy economy. Thirdly, the greenhouse gas balance and carbon balance of next generation biofuel technologies are considered to be much more favourable than those of conventional fuels, and more efficient use of land is made.

4.1.1 Examples of upcoming biodiesel technologies

For diesel engines, there are a number of technologies that have been put forward as *next generation* biofuels options:

- *Gasification* of biomass into synthesis gas ('syngas', a mixture of hydrogen gas and carbon monoxide), followed either by a Fischer-Tropsch reaction to make hydrocarbons ('synthetic diesel' or *Fischer-Tropsch diesel*) or catalytic conversion of syngas into methanol. Methanol can subsequently be converted to *e.g*. dimethyl ether (*DME*), which can be used as a gaseous 'LPG-like' diesel fuel. The production of syngas from coal, petroleum and natural gas is a commercial process, and the technology has been known for many years. Currently, Shell uses a natural gas-to-liquid (GTL) process to make low-sulfur diesel, hence the term biomass-to-liquid (BTL) for Fischer-Tropsch biodiesel. The major drawback is the enormous investment that is required. The research challenge is to make the process suitable for oxygen-rich biomass of a varying composition.
- *Pyrolysis* of biomass to yield *pyrolysis oil* or '*bio-oil*'. Dried biomass particles are treated at high temperatures in the absence of air or oxygen to yield a liquid, solid (char) and gaseous fraction. Fast pyrolysis increases the liquid fraction. However, the bio-oil is unstable, and contains many components that are detrimental to the diesel engine. Some consider pyrolysis merely as a convenient method to increase the density and energy content of biomass. Further processing, such as hydrogenation, is necessary to create higher quality biofuels. Pyrolysis oil has good potential as a heating oil or as a fuel for power generation.

- *Hydro-thermal upgrading* of biomass into '*HTU-diesel*'. In this process, wet biomass such as grass, sugar beet pulp or bagasse is treated at high pressures and temperatures –in the presence of water and, optionally, oxygen– to yield, after water removal, the so-called '*biocrude*', a tarry oil. Carbon dioxide is produced during the process, thereby reducing the oxygen content of the biomass. Upgrading of the biocrude by distillation or hydrogenation is required to obtain a fuel suitable for diesel engines. The technology was originally developed by Shell in the 1980s.
- *Hydrotreatment of vegetable oils and animal fats* with hydrogen gas, leading to hydrocarbons and a mixture of carbon dioxide, carbon monoxide and propane. The resulting hydrocarbons are similar to petrodiesel, and have a higher purity and some better fuel properties than diesel. Despite the fact that the technology is somewhat more forgiving than conventional biodiesel production when feedstock quality is concerned, it still uses 'first generation' feedstock. Hydrotreatment is a known refining technology in the petrochemical industry. Vegetable oils and animal fats can either be treated in a stand-alone operation, or can be co-processed together with petrodiesel. For instance, the company Neste Oil in Finland uses the stand-alone approach ('*NExBTL*'), whereas Petrobras in Brazil use co-processing to produce a diesel blend directly ('*H-Bio*').

4.2 Recent and future developments of fuel quality standards

Current discussions on biofuel standards focus on existing standards of conventional biofuels. Among the motives to change the current standards or even come to new standards are:
- the ambitious targets set by governments to increase the share of biofuels within transportation fuels;
- the restrictive European standard EN 14214, basically stating: *biodiesel = rapeseed methyl ester*;
- the increasing international trade of biofuels resources (*i.e.* vegetable oils) induced by the search for cheaper raw materials;
- the desire for improved test methods
- concerns for direct and indirect ecological effects of biofuels.

In order to increase the share of biodiesel, the European Commission has mandated the CEN to raise the share of biodiesel in blends from 5 to 10% (standard EN 590). It has also given a mandate to allow not only methyl esters, but also ethyl esters (FAEE) to be blended into diesel. For FAEE, a separate standard will be developed, which allows up to 10% to be blended into diesel. CEN has recently accepted both mandates, although it may take a while for the proposed changes to be effected.

Global biofuels standards could help to make biofuels such as biodiesel a successful internationally traded commodity. The United Nations have recently set up an International Biofuels Forum to investigate the feasibility of such international standards. Current members are representatives of the United States, Brazil, Europe, China, India and South Africa. Parallel to this, experts from the European, American and Brazilian standardization organizations have done a similar exercise, by grouping the properties into (1) those on which agreement can easily be obtained, (2) properties that are currently different but which can be harmonized after further investigation, and (3) properties that are too different to be deemed bridgeable in the foreseeable future. It was concluded that, due to regional differences that have been discussed before (climate, legislation, infrastructure, diesel composition), it is very unlikely that an international biodiesel standard harmonized on all requirements and test methods will ever be agreed upon. Instead, a '*two-tiered*' specification approach is supported. The first, or global, tier of specifications would provide a *base quality* for biofuels (*i.e.* biodiesel, bioethanol) produced and marketed in any region of the world. The second, or regional, tier of specifications would provide *fit-for-purpose qualities* based on the region where the biocomponents are going to be used. In any case, the quality of internationally traded fuels should not be compromised, since this would lead to increased harmful emissions, engine failures, and therefore a bad image of biofuels in general.

5 Conclusions

In order to reach the ambitious targets set by the EU government with regard to the share of biofuels in the transportation sector, feedstock for the production of biodiesel has to be imported. Brazil has excellent conditions for the growth of a wide variety of energy crops, and has proven with bioethanol that it can implement biofuels that can compete with existing petroleum fuels. The recent discussions on biofuels such as biodiesel are focusing on the food-for-fuel issue, land use change and reduction of biodiversity. However, if a global market for biofuels from agricultural crops is considered to be sustainable and feasible, the technical requirements of biofuels are also important. This is because the successful international trade of biofuels and its raw materials depends on the availability of good fuel quality standards.

The current European standard for biodiesel, EN 14214, is the most demanding biodiesel standard in the world. Basically, only rapeseed methyl ester of high purity is accepted as biodiesel, either as a neat fuel or in blends (up to 5%) in petrodiesel according to EN 590. Common vegetable oils from crops that are widely used in Brazil do not comply in their pure form to the European standard. Only blending of different methyl esters (*e.g.* from soy and palm) seems to be a realistic option. This also allows biodiesel producers to have more feedstock flexibility, and enables them to pick the most attractive raw materials (from a cost and quality point of view).

Now that more and more data on the engine performance and emissions of a variety of vegetable oil monoalkyl esters becomes available, an update of the existing standards seems appropriate. Although the car and OEM industry is anxious, it is expected that adapted or even new biodiesel standards will appear in the near future that will allow a wider variety of raw materials to be used.

A final important note is that quality standards do have an effect on sustainability, in the sense that restrictions with regard to feedstock and biodiesel production methods may lead to reduced biodiversity. In other words, the options to produce biofuels sustainably would increase significantly if, instead of only virgin rapeseed oil, also waste restaurant oils, animal fats and other waste oils and fats were allowed to be used as raw materials, provided of course that fuel performance is not impaired. The development and use of improved cold flow additives and other performance aids is also important in this respect. Much is expected from upcoming (second generation) technologies that can transform low cost biomass (waste, by-products and other material mostly consisting of lignocellulosic materials = fibre) into high quality fuels. As this lignocellulosic material is much more available than conventional biofuels feedstock (oil and) it should be possible to produce larger quantities in a sustainable way. Also, there is no (direct) competition with food and feed production, and the land use issue would be much less problematic.

Part 3. Sustainability of biodiesel from Brazil – GHG effects of feedstock cultivation and land use changes attributable to biodiesel demand

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1 Introduction

Demand for soybean has been rapidly growing in the past decade and will continue to grow to meet food and feed needs (Bindraban and Zuurbier, 2007). Increasing meat consumption in China leads to an accelerated demand for soybean feed for pork and chicken production. The portion of soybean oil for food has increased from 20% of world vegetable oil supply in 1990 to 24% in 2006 and will continue to grow at an increasing demand of some 3-4% per year (USDA, 2007). In addition to this demand, soybean will almost fully be used to supply feedstock for the production of bio-diesel in order to meet the obligatory blending targets for transport diesel as set by the Brazilian government (Stattman, Bindraban and Hospes, 2008).

Future soybean production for food and feed will put additional claim on land and other resources that may be accelerated soybean used for bio-diesel. Though soybean production has been driven by feed demand, increasing oil prices will serve as an additional driver for expanding soybean production. Soybean oil cannot simply be reallocated for use as biodiesel, because of the large and growing demand for oils for food.

In this chapter we will first provide a general overview of the expected soybean developments for the coming decade in Brazil. In the next section we will provide a description of the soil and vegetation characteristics of the Cerrado because by far the largest expansion will take place in this biome. We will then assess, given the limited availability of field data, the sustainability dimension of biodiesel from soybean, as far as the Green House Gas (GHG) balance is concerned for both direct; i.e. within the chain, and indirect effects, i.e. due to changes in land use. To be able to assess the ultimate impact of soybean production on land use and GHG emissions, analyses should be pursued based on scenarios. Scenario's provide insight in alternative developments and appears to be valuable in decision making. In this report, we have not elaborated the scenario's but did describe various available tools that could be used or modified for this purpose in future analyses. A brief analysis is made based on the available data for 2000 and 2002. The chapter concludes with some remarks on the role and consequences of soybean for biodiesel.

2 Developments in Brazilian soybean

2.1 Soybean for food and feed – production volumes

Projects made by the International Food Policy Research Institute (IFPRI) in 2001 for the year 2020 (Rosegrant *et al.*, 2001) showed the total production volume of the largest producers and consumers of soybean to increase from 130 million tons in 1997 to 200 in 2020 (Table 3.1). Then, the United States was expected to strengthen its positions as largest soybean exporter at over 30 millions tons and to raise its total production volume to almost 95 million tons. The Latin American countries Argentina and Brazil were expected to substantially increase their export volumes to close to 20 million tons each. The EU15 would remain the largest importer at 19 million tons followed by China with 12 million tons. Overall, total production and trade volumes estimated through the econometric approach of the IFPRI were grossly underestimating actual soybean developments. The total production volume of 235 million tons of soybean today (2006/7) already exceeds the estimated global production of 227 million tons in 2020 by the IFPRI (Rosegrant *et al.*, 2001), and export volumes are much higher today that anticipated for 2020.

These facts point the enormous strength of the drivers for soybean production. One of the main drivers for the demand of soybean is feed for chicken and pork. The IFPRI projected global meat production to increase from 208 in 1997 to 326 million tons in 2020. Virtually all the increase in consumption of meat can be attributed to developing countries up from 110.5 in 1997 to 212.3 million tons in 2020, half of which is to the account of China alone. The consumption increase in developed nations will remain modest from 97.7 to 114.3 million tons. As with soybean, these estimates may be considered to be conservative. Total meat production in 2004 reached 260 million tons with beef, chicken and pig meat accounting for 60, 68 and 100 million tons, respectively (FAO, 2007).

ABIOVE (2005) more recently projected future production volumes of soybean taking production levels in 2005 as a starting point. They project global soybean production to increase to 280 million tons already in 2015, reaching 307 million tons in 2020. Brazil's share will increase to 92 million tons in 2015 and 105 million tons in 2020, surpassing production by the USA of 83 and 87 million tons in those years. Argentina is expected to produce 51 and 58 million tons in 2015 and 2020, respectively, with comparable volumes of 52 and 57 million tons by all other producers together.

Note the rapid expansion of soybean production in India. While most are concerned about the rapid demand from China, Indian consumption of poultry is rapidly increasing as is its production of soybeans.

Table 3.1. Actual (1997) and projected soybean production by IFPRI (Rosegrant *et al.*, 2001), and ABIOVE (2005) as compared to actual production levels in 2006/7 (Oil World Annual, 2007) (*10^6 tons).

	Actual production in 1997	**Projected for 2020 (IFPRI, 2001)**	**Actual production in 2006/7 (Oil World, 2007)**	**Projected in 2005 ABIOVE (2005)**	
				2015	**2020**
Argentina	14.1	26.8	46	51	58
Brazil	27.1	48.1	59	92	105
United States	70.9	94.9	87	83	87
EU15	1.4	1.9	1.3	52**	57**
China	14.3	25.5	16		
Southeast Asia	2.0	3.1	8*		
World	144	227	235	280	307

* India only.

** Applies to EU15, China and Southeast Asia together.

2.2 Soybean for food and feed – acreage

The acreage of soybean has been expanding rapidly over the past decades in Brazil, and other South American countries. This expansion is expected to continue or even accelerate during the coming decade or two. Linear extrapolation is used to get an initial impression of the expansion, though this methodology does not take any driving factors for the past expansion into account. In Figure 3.1 the expected increase is assessed by extrapolating the trend from 1995 to 2007 towards 2020. Extrapolation of the area in itself does not reflect an important underlying factor, i.e. the increase in soybean yield. Correction for this expected yield increase, as presented in Figure 3.2, reduced the required area shown by the gray dots in the figure.

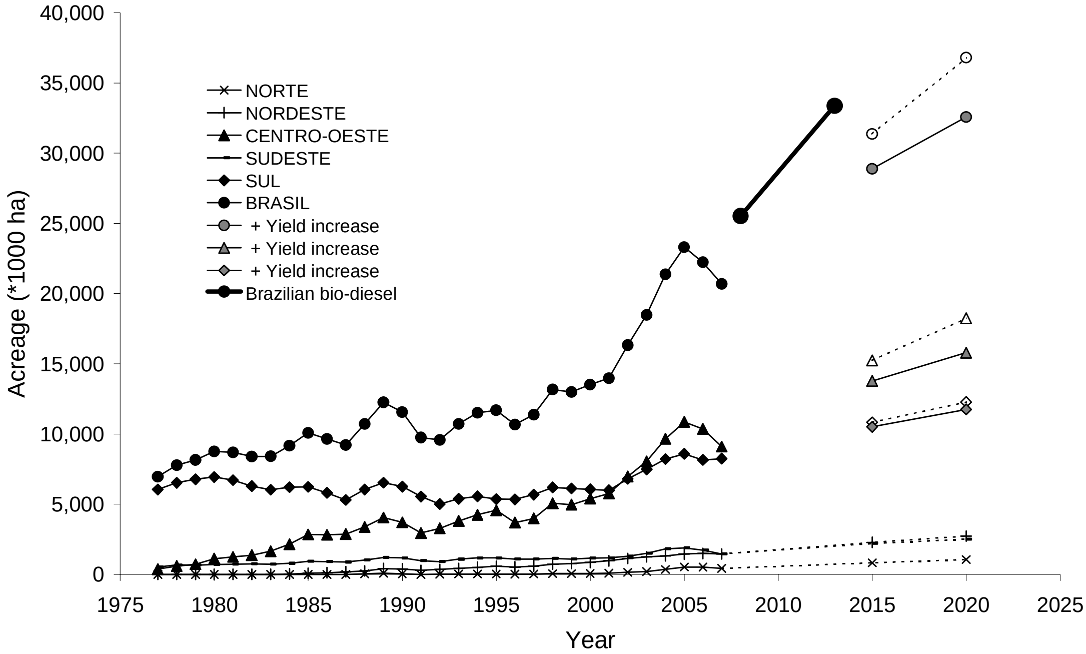

Figure 3.1. Changes in soybean acreage over the past three decades for different regions in Brazil. Extrapolated acreage based on the period 1995-2007 (Open symbols). Gray symbols represent corrected acreage for yield increase (obtained from figure 2). The black circles indicate the total acreage to satisfy the Brazilian targets for bio-diesel when fully obtained from soybean (see text below).

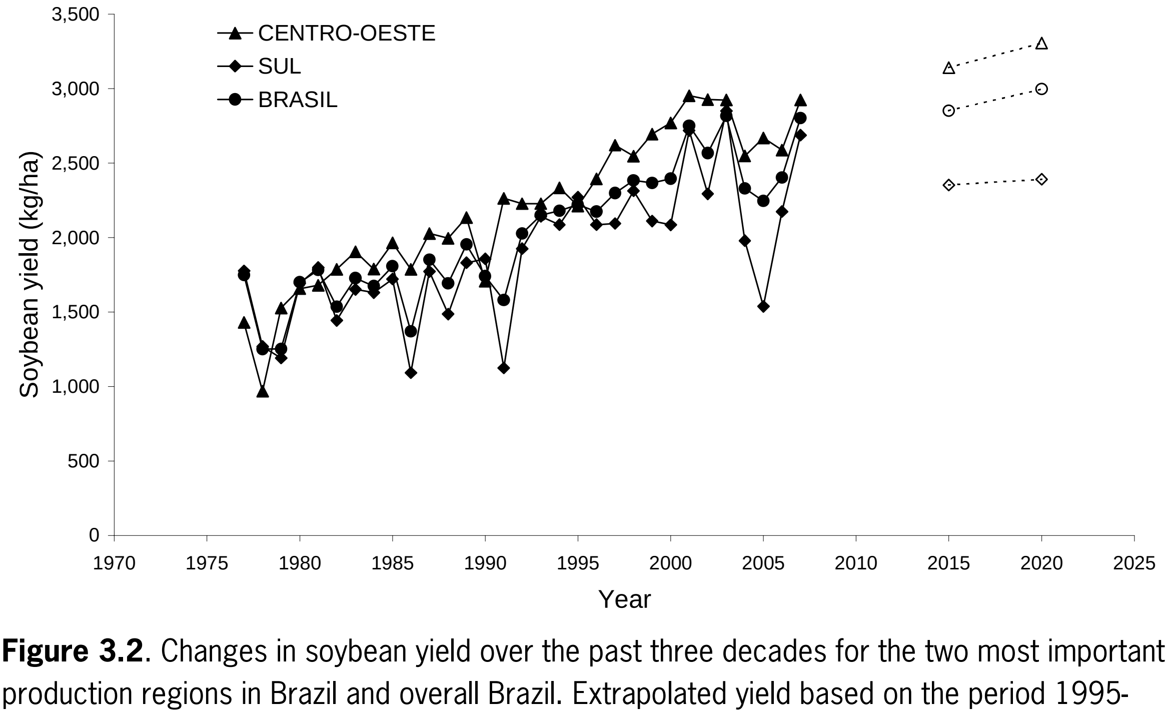

Figure 3.2. Changes in soybean yield over the past three decades for the two most important production regions in Brazil and overall Brazil. Extrapolated yield based on the period 1995-2007.

The total soybean acreage in Brazil is likely to increase from the current 22 million hectares to 29 million in 2015 up to almost 33 million hectares in 2020 (Table 3.2). The extrapolated production volumes (Figure 3.3) suggest volumetric estimates that are close to projections by ABIOVE in 2005 (Table 3.1).

Table 3.2. Estimated changes in soybean acreage for the coming 15 years (based on extrapolations in figure 1-3) to meet food and feed demand. These extrapolations do not take production of soybeans for bio-diesel into account.

	2005-2007	**2015**	**2020**
Central-East	10.1	13.8	15.8
South	8.3	10.5	11.8
Rest	3.6	4.7	5.2
Brazil	22.1	28.9	32.6

It is important to note that by far the largest proportion of the expansion of soybean acreage will occur in the Cerrado region. In assessing sustainability of soybean cultivation for bio-diesel we therefore look at the specific conditions of the Cerrado biome.

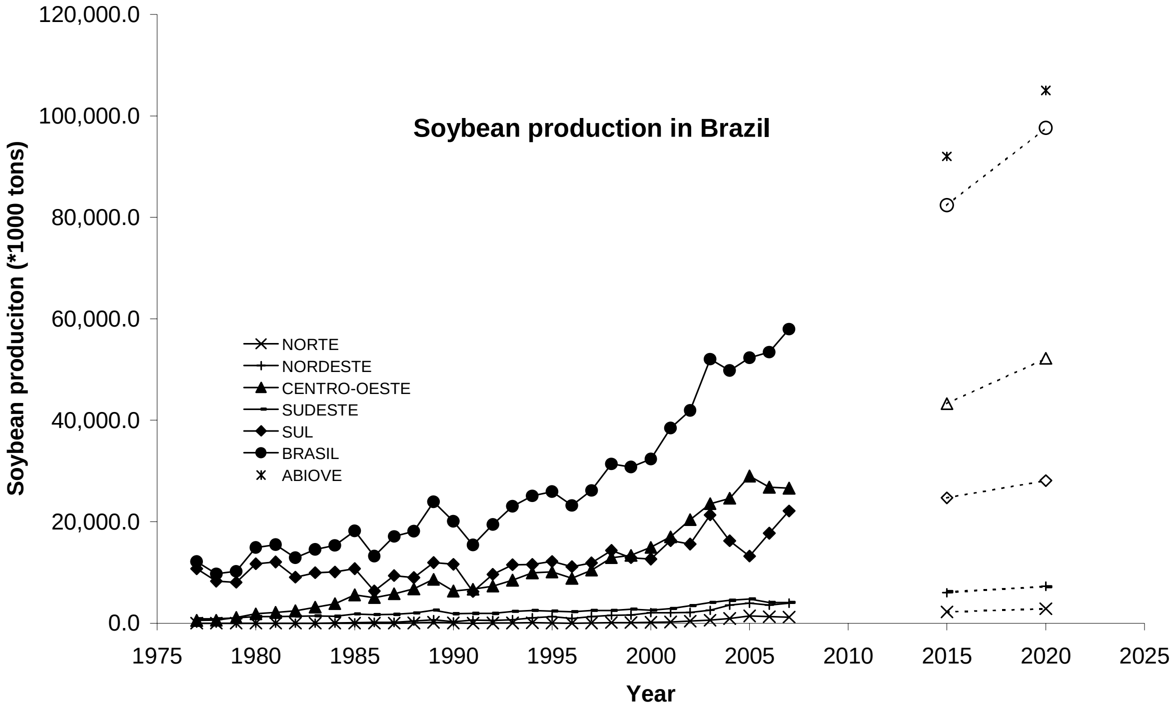

Figure 3.3. Increase in soybean production volume over the past three decades and extrapolated amounts till 2020. Extrapolations are based on the period 1995-2007. The estimates by ABIOVE (asterisk in the graph) suggest even slightly higher demand for soybean.

2.3 Soybean for biodiesel

Brazil has set legal standards for the blending of bio-diesel in its transport diesel amounting to 840 million litres for a 2% blending in 2008 (B2-goal) and 2100 million litres for a 5% blending in 2013 (B5-goal) (Brazilian Ministry of Agriculture, 2006). Currently (2004) almost 90% of the vegetable oil production in Brazil is derived from soybean. Cotton provides some 4.3% followed by palm oil that accounts for 2.2%. As crops other than soybean are not likely to assume a more important role in the production of vegetable oils for bio-diesel, we can safely assume that soybean is likely to supply the major share of the feedstock for bio-diesel for the coming 5 to even 10 years.

Under the assumption that all bio-diesel would be provided by soybean, the additional acreage in 2008 would reach 1.8 million hectares at a current production level of 2.65 t ha^{-1} and a total oil content of 18%, to satisfy the B2-goal. At the same yield level, the additional acreage would reach 4.4 million hectare for 2013 (B5). With yields increasing to 2.79 t ha^{-1} in 2013, the acreage needed would decrease to 4.2 million hectares. The bold line with dark circles in Figure 3.1 shows the total acreage required for soybean cultivation, including these areas for bio-diesel.

Each hectare of soybean at a yield level of 2.65 t ha^{-1} produces 477 kg of soybean oil. For every million kg of biodiesel (equivalent to 1.100.000 litres of biodiesel) a total acreage of 2100 hectares are required. Total energy use in the Netherland for transport in 2006 equals 500 PJ, on a total energy use of 3230 PJ (SER, website). As diesel contributes to half of the transport energy a total of 250 PJ would be required to cover current diesel demand for the Netherlands equivalent to 12.2 million hectares of soybean. At target volumes of 5.75%, 10 and 30%, 0.70, 1.20 and 3.7 million hectares of soybean will be required. These acreages however do not reflect the net energy efficiencies and need to be corrected for the energy required for the production of soybean, such as the fuel for the tractors or for the production and transport of fertilizers, etc. Transportation of the feedstock to processing factories after harvest and the processes of the feedstock also incur energy losses. Applying a rather generous overall efficiency of 50% implies the claim on cultivation acreages of 1.4, 2.4 and 7.2 million hectares of soybean at target volumes of 5.75%, 10 and 30% for the Netherlands. Acreages will be higher at lower efficiency rates of energy extraction, i.e. 2.1, 3.6 and 11.1 million hectares at 33% net energy efficiency.

3 Characteristics of the Cerrado biome

As the largest part of the expansion of soybean cultivation will take place in the Cerrado, we provide a general description of the characteristics of the Cerrado.

3.1 General

The Brazilian Cerrado originally covered over 2 million km2 representing about 23% of the land surface of the country (Figure 3.4).

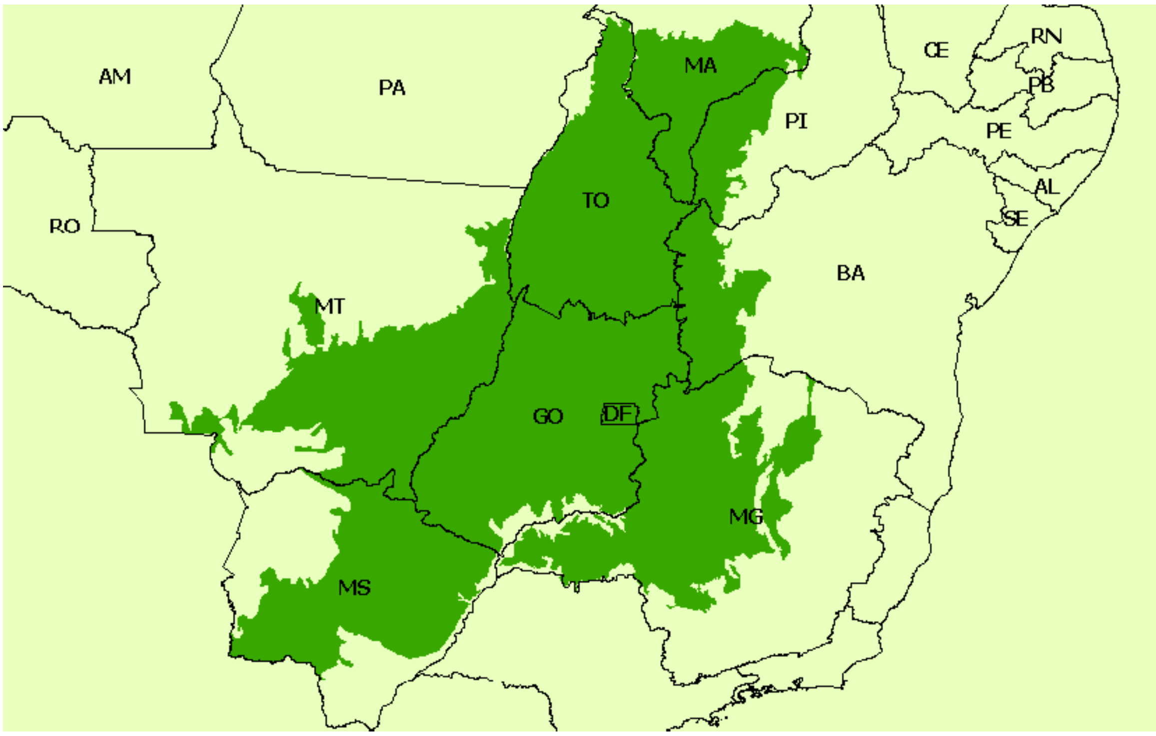

Figure 3.4. The core area of the Cerrado region in Brazil.

The Cerrado region extends from the margin of the Amazonian forest in the north and west, the Caatinga in the northeast, and Atlantic forest in the east to the borders of Parana and São Paulo State. The Cerrado itself varies in form, ranging from dense grassland (Cerrado lenhosa), usually with a sparse cover of shrubs and trees, to an almost closed woodland (Cerradão) with a canopy height of 12–15 m (Figure 3.5). A brief summary of the Brazilian Cerrado vegetation and threats to its biodiversity is given by

Ratter *et al.* (1997), while Eiten (1972) provides a review of the knowledge of the biome 30 years ago.

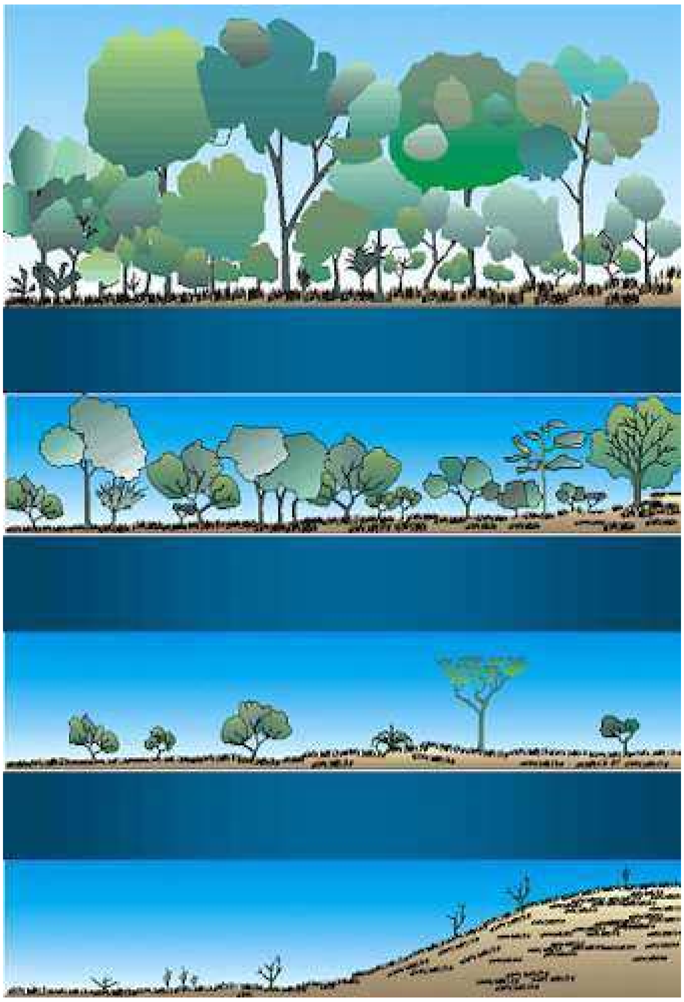

Figure 3.5. The physiognomy of the Cerrado.

→ Forested Cerrado (Cerradão)

→ Shrub Cerrado

→ Open Cerrado

→ Grass Cerrado (Cerrado limpo)

The Cerrado landscape is characterised by extensive savannah formations intercepted by rivers with riparian forests and smaller and larger wetlands. The largest wetland that is receiving Cerrado water is the Pantanal (250.000 km2) in which the rivers Paraguay, Cuiabá, Taquarí and Miranda join. In the Chapadas at higher altitudes alpine pastures can be found and at fertile soils well developed mesophytic forests. Urban pressure and the rapid establishment of agricultural activities in the region have rapidly reduced its natural vegetation and biodiversity. Until the mid 60's agricultural activities in the Cerrados were very limited. These activities were directed mainly at the extensive production of beef cattle for subsistence or the local market, since soils are naturally infertile for agricultural production. After this period, however, the urban and industrial development of the southeast part of Brazil forced agriculture to move to this region. The founding of the

capital city Brasilia with its infrastructure has been another catalytic process for development of the Cerrado. Over 67% of the Cerrado eco-region has been converted or modified in a major way. According to WWF, only 1% of the total area of the Cerrado Region is protected in parks or reserves (Mantovani & Pereira 1998).
From 1975 until the beginning of the 80's, many governmental programs have been launched with the intent of stimulating the development of the Cerrado region. As a result, there has been a significant increase in agricultural and cattle production. Nowadays the Cerrado region produces more than 70% of the beef cattle production in the country and thanks to irrigation and soil improvement it has become the important production centre of grain, soy, beans, maize and rice.
The Cerrado region is drained by the Amazon, the Parana-Plata en the São Francisco River. The dominant climate is seasonal tropical with dry and wet seasons. In the dry season natural fire can occur occasionally. The annual average temperature is 25ºC, reaching 40ºC in hot periods. The minimum is about 10ºC in May-July. The annual average precipitation is between 1200 and 1800 mm with the highest in the west in the period March-October. In the regions where the open pasture dominates the climate is hot; dry and rain periods with sporadic spontaneous fires. Trees are adapted to this climate with deep rooting trees and thick corky bark protecting against fire.

3.2 Soil conditions Cerrado

In the Cerrado biome soils are slightly acid in the range of pH 4 to 6 with a median at 5.0. A pH value higher than 5.3 prevents toxicity of microelements like aluminium, which necessitate the application of lime. Soil phosphorus should be adequately available to stimulate this symbiotic process of soybeans with rhizobium to fix nitrogen, and the soil pH should not be too low. Soluble soil phosphorus content on average is about 0.4 ppm, which is far below the recommended levels for plant growth (Yamada, 1983). Expressed in PBray, available P levels are lower than 7 ppm in almost 90% of the soils, indicating that the vast majority of the soils are deficient in P for most annual crops. Potassium availability in most of the soils is low as well. While organic matter content of the soils are often moderate to high, the Cation Exchange Capacity is low which makes the soils sensitive to leaching of, for instance, potassium (Cochran *et al.*, 1985). Soils are also sensitive to erosion, especially in areas where clay content is low.

By simultaneous liming to raise pH and applying phosphorus and potassium in a zero tillage system, the limitations of the soil conditions could be overcome which gave way for the exploitation of the Cerrado for soybean cultivation. No-tillage practices have reduced costs and crop residues may protect the soil from erosion. Expressed per hectare in relation to other crops, soybean by far exceeds the requirement of total fertilizers, primarily phosphorus and potassium, followed by maize that requires nitrogen as well. Brazil uses about 10% of worlds P2O5 fertilizers, while it produces less than 4% of the global rock phosphates and therefore relies on substantial imports (ANDA, 2005).

3.3 Biodiversity and water

To date, the majority of research studying tropical diversity is focused on tropical rain forests, since they represent by far the most species-rich ecosystems (Valencia *et al.*, 1994). Tropical savannah systems can also be extremely species rich (see, e.g. Mistry, 2000) The Cerrado biome of central Brazil is one such example. Mendonça *et al.* (1998) have shown that the Cerrado biome contains at least 6670 species of higher plants. Dias (1992) believes the number to be greater than 10,000. The species richness of trees and large shrubs are estimated between ca. 1000 and 2000 species (Castro and Martins 1999; Ratter *et al.*, 2003).
Over the last 30 years there has been an explosion of research into the biodiversity of the Cerrado. The Cerrado is a global biodiversity 'hot spot' as has been reported recently (Myers *et al.*, 2000) and that this biodiversity is under great threat, with little over 35% of the original area of the biome now remaining intact (Cavalcanti and Joli, 2002).

The Cerrado flora is composed largely of the same plant families and many of the genera of the Amazon and Mata atlantica, but at the species level its flora is very distinct. There is reliable floristic information for tree and large shrub species across the biome.
There are nine distinct floristic provinces within the Cerrado, however, no comparative studies have been conducted on their respective floras, and the detailed 'large scale' patterns of plant diversity remain obscure. Conservation of biodiversity will necessitate choices among areas and for the Cerrado there is an urgent need for clear data on floristic distributions. A multi-disciplinary workshop on Cerrado conservation held in Brasília in 1998 (Cavalcanti and Joli, 2002) attempted to prioritise conservation initiatives within the biome.
The biodiversity of Cerrado is not only high for trees and shrubs. For only three orders of insects (Lepidoptera, Hymenoptera, and Isoptera) there are 14,425 species recorded, representing at least 47 percent of the species of those orders in Brazil (Cavalcanti and Joli, 2002). Biodiversity of the Cerrado is comprised by at least 10,400 species of vascular plants, 780 fish species, 180 reptile species, 113 amphibian species, 837 bird species and 195 mammals (Cavalcanti 1999). Most of these species are restricted to cerrado. The percentage of endemic species varies among taxonomic groups, from 4 percent in birds to 50 percent in vascular plants. Cerrado is also a unique evolutionary tension zone, where species from the largest South American forests (Amazon and Atlantic Forest) and from the largest South American dry habitats (Chaco and Caatinga) intertwine (Silva 1995).

3.4 Regional diversity

Furley *et al* (1999) in their study on the diversity of the Cerrado counted 951 woody species 494 species (52%) are found only in a single floristic province, with very few species (37, i.e., 4%) occurring in all six provinces. Excluding the disjunct Amazonian province still only 76 species (8% of the total) are found in all the other five floristic provinces. These data support the findings of Ratter *et al*. (1996, 2003) and Furley (1999) that the Cerrado is extremely heterogeneous. There is a relatively low number of generalist Cerrado species; the majority is region specific. That means that there is high - diversity in the Brazilian Cerrado.

There are a number of variations from this pattern of widespread dominants. Ecological differences between the regions emerge from the lists of species defining each region. An example of this is the strong tendency of the far western and central-western sites to be dominated by species characteristic of mesotrophic soils and the very low occurrence of such species in the dystrophic cerrados of the south (Ratter *et al*., 1973, 1977; Furley and Ratter 1988). Although over 40% of the cerrado woody flora is endemic to the biome (Cavalcanti 1999), a significant proportion (varying between 1.6 and 17.5%) is further localised and apparently restricted to one of the six floristic provinces. The western Cerrados show the least similarity with all other areas (between 0.340 and 0.458 Sörensen Index). Each province shares between ca. 25% (minimum) and ca. 85% (maximum) of its species with each of the other provinces.

There are broad-scale b-diversity patterns which should assist conservation planning. Although a suite of ca. 121 woody species occur widely throughout the biome, the majority of the species in the biome have more restricted distributions. To conserve all the plant diversity present in the Cerrado, conservation areas should be established across the biome and a regional focus (at the scale of the floristic province) is an important concept in ensuring that biodiversity is adequately protected. The available data indicate that dominance patterns within the Cerrado are similar to those of Amazonian rain forests.

3.5 Water processes in the Cerrado

Important rivers find their origin in the Cerrado region such as the Parana, São Francisco and a part of the Amazon tributaries. For the Taquarí (catchment size 78.000 km2) a hydrological model has been made. The model is able to simulate surface water flow as well as the flow in the saturated zone and the unsaturated zone. Calibration of the model has been carried out on the basis of measured discharges. The Taquarí headwaters are situated in the Cerrado, while its alluvial fan is in the Pantanal. Although the Taquarí catchment is assumed to be very narrow at the intersection between the Cerrado and the Pantanal it is not for sure that groundwater flow is limited to the borders of the surface water system. In the Taquarí catchment the Cerrado has been cultivated and has developed from natural vegetation in the 1970s into a cattle breeding and agricultural land in the 1990s. Figure 3.6 shows the development of cultivated land use for the years 1976, 1984 and 1991.

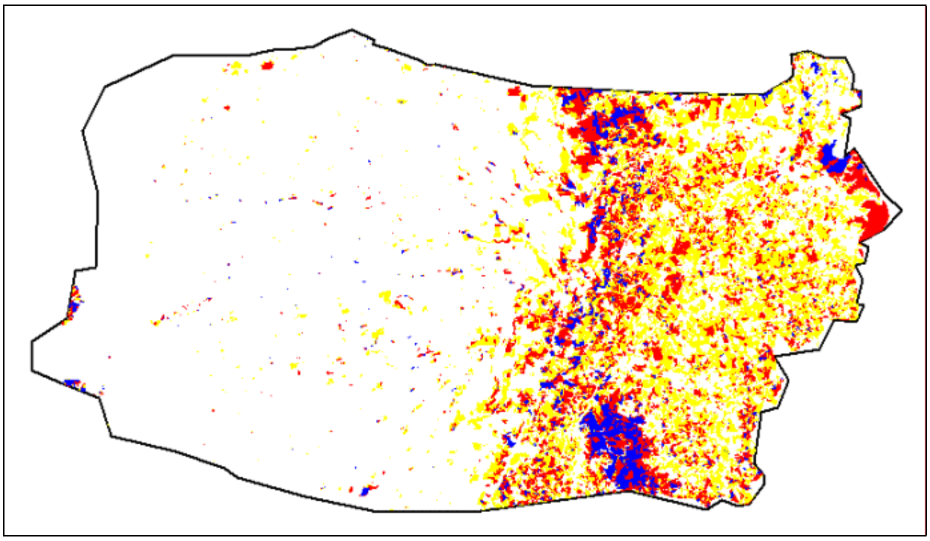

Figure 3.6. Cultivated land in the Taquarí catchment in 1976 (blue), 1984 (blue + red) and 1991 (blue + red + yellow).

The groundwater module that we used has a quasi three-dimensional approach in groundwater modelling. Evapotranspiration is determined by the vegetation and the moisture content in the root zone. Potential evapotranspiration can be defined at daily and nodal scale. However, potential evapotranspiration data is not available is such a variety as rainfall data. The dynamics of the movement of surface water through open watercourses evolve much faster than groundwater. The average monthly discharge is reflected well in the model outcome.

At Coxim at the edge between Cerrado and Pantanal, the rise and fall of discharge peaks is a very frequent appearing phenomenon. This might also be the result of the fact that the discharge at this location along the Taquarí River is approximated with the sum of the discharges of the two upstream rivers.

From the modelling of the water flows we can conclude that increase of precipitation has large effects on the hydrology of rivers in the Pantanal, but the changes are also caused by the changing of the vegetation cover on the Planalto that is part of the Cerrado (Table 3.3). The most logical explanation for the increase in discharge at Coxim is the decrease in evapotranspiration due to the conversion from natural savannah vegetation to cultivated land. The difference between the water flow in 1974 and 1994 at Coxim is 30%

to 40% (Figure 3.7). Because of the high percentage of erosive soils in the upstream part of the Taquarí (PCBAP, 1994), this also can explain the high sediment load transported by the river.

Table 3.3. Vegetation cover change in the period 1974-1991 in the Cerrado of the Taquarí river catchment (Oliveira *et al.*, 2000).

Vegetation change	**1974**	**1984**	**1991**	**% change (annual crops + grassand 1991/1994)**
Annual crops (%)	2,0	6,9	11,4	5,7
Cultivated grassland (%)	1,4	35,5	41,6	40,8
Native vegetation (%)	96,6	57,6	46,0	-0,47

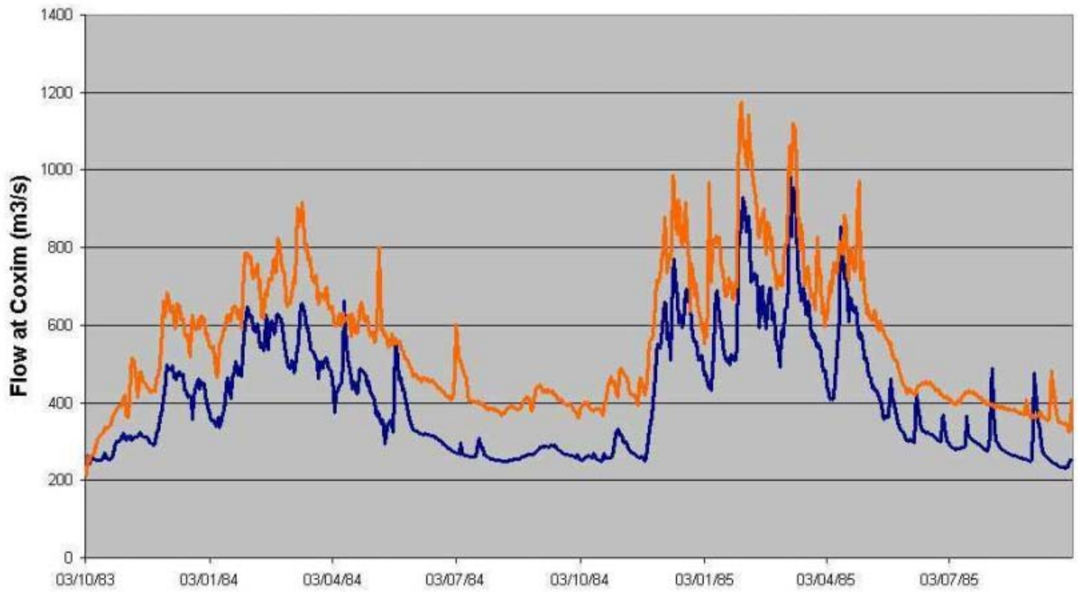

Figure 3.7. Discharge at Coxim comparing 1974 (blue) and 1994 (orange): difference 30-40% (Jongman, 2006).

For sustainable land use it is important to model and evaluate the changes in water discharge and sediment load of other rivers in Cerrado regions where cultivation of the Cerrado is taking place.

4 Sustainability – crop and land use

The Cramer committee has developed sustainability criteria for biomass for biofuels that comprise 9 elements (see for details chapter 1). Whereas these criteria cover a range of ecological, social and economic indicators here we emphasize the criteria on Greenhouse Gas Emissions. We will also reflect briefly on biodiversity loss. The Cramer criteria consider GHG emissions at the field level only. In our analysis, we will look into potential losses that occur when natural lands are converted directly or indirectly for the production of soybeans for bio-diesel. Life Cycle Analyses are used to provide overviews of the net balance of energy of GHG emissions. For soybean, however, Yong Li and colleagues (2006) only looked into the processing of soybean oil. LCA's on direct cultivation of soybean and effects due to indirect land use change have not been reported in so far we have been able to trace literature. Even though recently estimates of these effects have been reported and are hotly debated.

4.1 GHG balance at field scale

The GHG balance should be such that the final emissions of GHG, expressed in CO_2, will replace a certain fraction of the emissions when using fossil fuels. Apart from CO_2, emissions of N_2O should be accounted form in these balances as N_2O has a radiative forcing as high as 296 time that of CO_2.

A net GHG balance should be estimated taking into account energy and other input requirements for cultivating and harvesting the crop, and for the production of inputs like fertilizers and pesticides. Crop management will have a significant effect of the effectiveness with which GHG can be saved. A soybean field that is poorly managed with low yields may likely give more unfavourable balances than properly managed fields with high yield levels. On the other hand, the optimal management practice may depend on the objective for which the crops are cultivated. To obtain an optimal GHG balance, lower fertilizer amounts may need to be applied, for instance, than to attain highest yield levels. At the same time, there is a direct relation between management practices and sustainability aspects such as losses of nutrients and pesticides to the groundwater, emissions of gases to the air and the fertility status of the soils (e.g. Bindraban and Conijn, 2007). An overview of the factors to be considered in an analysis of the GHG balance is given in Figure 3.8.

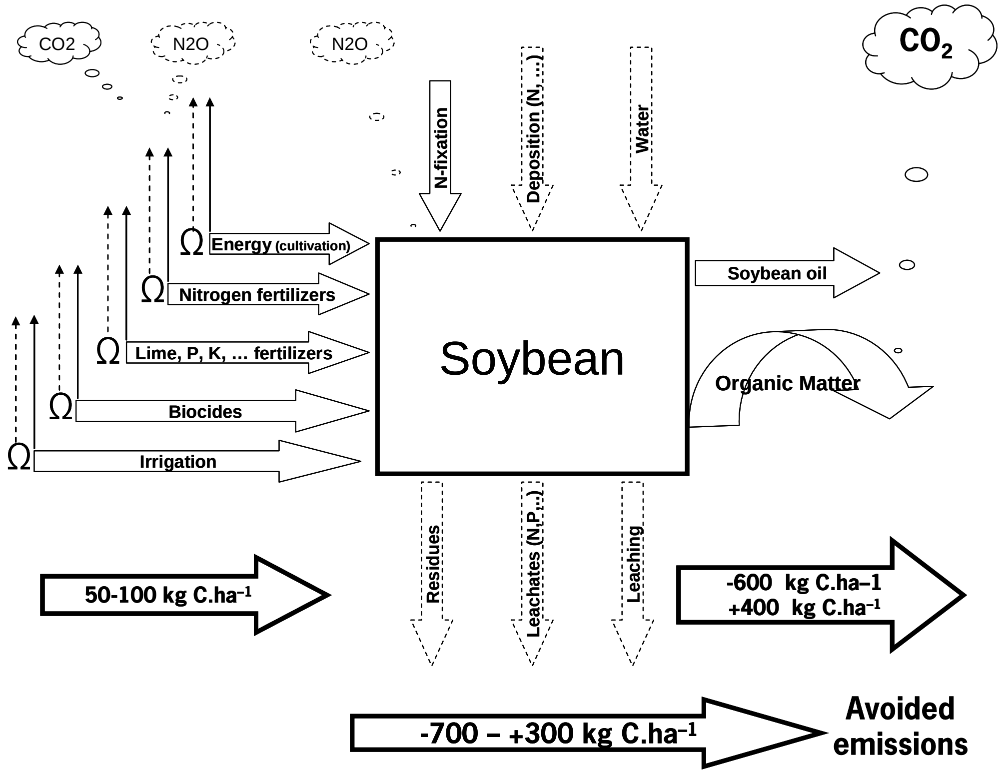

Figure 3.8. Factors to be considered in estimating GHG balances for soybean cultivation. Symbols are explained in the text below.

Information on the quantities of inputs used in soybean cultivation and the losses to the environment cannot be given precisely as they vary strongly depending on the location, environmental conditions and cropping systems. Here relevant issues to be considered in detailing these assessments are dealt with.

Any input used during cultivation is produced and transported to the farm or field which is reflected by the Ω-signs. Here the energy needed to produce inputs like equipments such as tractors, and fertilizers may be included. In these processes emissions of CO_2 and N_2O, but also other GHG may occur that ought to be incorporated in the balance analysis.

Activities including sowing, application of agro-chemicals, weeding and harvest may require tractor input run on fuel. As most of the soybean in Brazil is grown under zero-tillage, no energy is needed for preparing the land prior to sowing. As a reference for a general indication only, approximately 50 litres of diesel is used per ha for the production of wheat in the Netherlands, where each litter emits 3.1 kg CO_2.

N_2O emissions result from the use of nitrogen fertilizers, while GHG emissions in the production and transport of these fertilizers should be accounted for as well. In the GHG balance for soybean in Brazil, we need, however, not include N_2O emissions as soybean is not supplied with nitrogen fertilizers. Experiments show no yield response even up to application rates of 400 kg N ha^{-1}. Soybean is a leguminous crop that provides its own nitrogen by fixing nitrogen from the air in symbioses with rhizobium. Brazil is the only country that does strain selection of rhizobia to increase N-fixation which turns out to be highly successful in eliminating nitrogen fertilization (Hungaria, person comm). N2 is converted in this process into 'active nitrogen' in the form of proteins and other components in the plant, that might be lost in the form of N_2O from crop residues left on the ground. These processes should be accounted for in a GHG balance analysis.

Heavy doses of lime are applied to the rather acid soils of the Cerrado and energy costs to mine, process, transport and apply the lime should be accounted for. Lime application depends on soil acidity, to reduce aluminium toxicity levels and increased the uptake efficiency of nutrients, especially the poorly available phosphorus (Embrapa Informação Technológia, 2004). Applications may range from 700 to over 3200 kg ha^{-1} to correct soil acidity. Phosphorus (P2O5) and potassium (K2O) require energy equivalent to some 0.32 and 0.38 kg CO_2 per kg. As every ton of soybeans taken from the field contains 10 and 20 kg P2O5 and K2O, respectively, minimal amounts of 30 and 60 kg of these fertilizers should be applied at average yield levels nearing 3 tons ha^{-1}, assuming all litter to remain on the field and recovery reach near full uptake efficiency. Much higher initial applications are however needed for soil correction in order to raise availability levels of these nutrients for plant growth. Actual application rates for correcting soil P and K range from 60–240 for P2O5 and 50–100 for K2O depending on soil characteristics. Phosphorus application rates in the Cerrado may roughly double application rates in the southern states of Brazil like Paraná (Embrapa Soja, 2006a; b; Embrapa Informação Technológia, 2004). Adequate amounts of potassium are important especially to get good quality grains. In addition, several kilograms of fertilizers are needed to correction and availability of micro nutrients. Cobalt and molybdenum are important for instance for optimal N-fixation.

Little irrigation is used for soybean cultivation, though the number of pivot centres is increasing in the Cerrado. Energy used for operating the equipment should be included in the balance. Biocides require, in the form of applicable product and not active ingredient requires an equivalent of 3.3. kg CO_2 per kg. The mounts of biocides use different among production systems but should be accounted for as well in the GHG balance.

Accounting for these various inputs leads to a rough estimate for the total energy input required for cultivating soybean equivalent to some 50–100 kg C ha^{-1}.

The largest uncertainty with regards to C losses relates to the changes in soil organic matter. Here up to 1000 kg C ha^{-1} can be lost under poor management while these losses can be reduced to virtually nothing when judiciously managed in rotational systems. The organic matter (OM) content of the soils was found to decrease with continuous cultivation of soybean. Under 5 year of continuous cultivation of soybean, Da Silva *et al.* (1994) found the rate of loss of OM to range from 0.24 to 0.32% per year in sandy and clayey soils, respectively. The initial organic matter content in the clayey soils was 2.7% and for the sandy soils 1.5. The decreasing OM content was associated with decreasing Cation Exchange Capacity. De Maria and De Castro (1993) found OM content to decrease equally in no-till systems as in tilled systems, decreasing from almost 5% to some 3% in 7 years in the top 5 cm. Similar rates of decrease were found for deeper layer, where the OM contents were lower overall. Continuous cultivation of soybean therefore seems detrimental to soil quality in the long run.

Rotation of soybean with other crops may however prevent the slow but steady degradation of soils. Bustamante and colleagues (2006) simulated the dynamics of C and N in soils after conversion of native Cerrado vegetation over a period of 30 years. Soil C and N content declined steadily by one-third over 30 years under soybean monoculture with conventional and no-tillage practices. In contrast, the soil C content was sustained under a rotational no-tillage system of soybean with millet as a cover crop and also with maize. Soil nitrogen content even increased under these rotational systems due to the increased inputs of N. It should be realized that the N_2O losses associated to these applications of nitrogen to the rotation crop should, at least partly, be allocated to soybean as well, as it prevents loss of OM in the soil due to soybean cultivation.

Finally, each hectare of soybean at yield levels of 2.6–2.8 t ha^{-1} produces some 475–500 kg of soybean oil. Soybean oil contains 77% C which equals 365–385 kg C per hectare.

Consequently, the net balance of C in soybean cultivation is likely to show a wide range. Losses up to 700 kg C ha^{-1} may occur under poor management primarily due to the loss of soil OM. Under proper management in rotational systems, 'saving' of 300 kg C ha^{-1} could be realized, though the emissions of N_2O from the N-fertilized rotational crop need to be subtracted. Moreover, as soybean is not only grown for the production of soybean oil, but for protein also, a proper way of assigning the gains or losses of GHG emissions should be identified to these different components. As a first rough indication only, it may be assumed that soybean for bio-diesel may not contribute significantly to save GHG emissions.

4.2 Land use change

Due to the expansion of the land area for the cultivation of energy crops, changes in above ground and below ground carbon stock should be included in estimating the contribution that biodiesel could make to reduce global GHG emissions.

In Brazil, forest or savannah land is cleared for wood and charcoal and is hence converted into grasslands for cattle raising. After 5 to 10 years, these grazing lands may be converted into cultivation land for soybean, sugarcane or other crops. There is a general assumption in Brazil that no additional land needs to be cleared for the expansion of these arable crops. By increasing the productivity of the 220 million hectares of grasslands by 10–15%, the required 25–30 million hectares for the expansion of these crops can be absorbed. Under this scenario, the changes in C-balance of above and below ground due to conversion from grassland to arable land, should be included in the GHG balance of bio-diesel.

For assessing the likelihood of the above scenario of increased productivity of grasslands, a quick overview of grassland and meat production is presented (Barioni, pers. comm.). The expansion of grassland in the Cerrado occurred predominantly because of the introduction of the African grass species Brachiaria in the 70's that turned out to be well adapted to the soil conditions. Intensification of animal production has recently progressed and productivity has increased from 28 to over 42 kg per head per year in the last 17 years. These gains were mainly obtained from supplemental feeding. Consequently, the increase in productivity was more related to improvement in the performance per animal, rather than productivity increase per hectare of grassland. Stocking rates remained stable at somewhat less than a head per hectare. Improvement of productivity per hectare will be obtained with high investments to increase the pH of the soils by liming and improve the P-status by fertilization. Also, land appreciation in the agricultural frontier, along with some other economic drivers for competitive production for exports may have limited the intensification in pasture production. It hence appears to be a large number of strongly interacting factors drive the productivity of grassland and meat, which may as well remain stagnant for the coming 10 to 15 years.

For the analyses of the GHG balance we therefore considered a second scenario assuming that the grassland productivity may not increase. Under this assumption of stagnating grassland productivity, replacement of grassland by soybean (and/or sugarcane or other crops) will lead to the clearing of natural lands for the installation of grasslands. Though it concerns an indirect effect of land clearing for the production of bio-fuels, any change (losses of GHG) resulting from these indirect conversions should be included in the GHG balances for bio-diesel production. In the end, it makes no difference to the atmosphere whether the emissions from land clearing come from land cleared directly or indirectly for fuel.

A preliminary overview of the possible changes in above and below ground carbon contents is provided in Figure 3.9. Above ground biomass of Cerrado vegetation may range from 20 to 80 tons of Carbon per hectare. As a rule of thumb, twice as much organic matter is found below ground as above ground. Total amounts up to 200 tons have been reported for a soil depth of 1 meter. Total above ground biomass reduces when converting Cerrado natural vegetation into grassland and below ground biomass declines overall. Similarly, losses appear to be higher when continuing the transformation to arable lands. The wide range of uncertainty in the estimates calls for specification of the data to location and production systems. This would allow distinguishing between poorly and less poorly performing system transformations. Total losses of carbon and other GHG might therefore exceed potential savings manifold, suggesting that it might take several decades to over a hundred year to recover initial losses. Obviously, the losses related to these land use changes should be analysed in much more detail starting form a production ecological perspective.

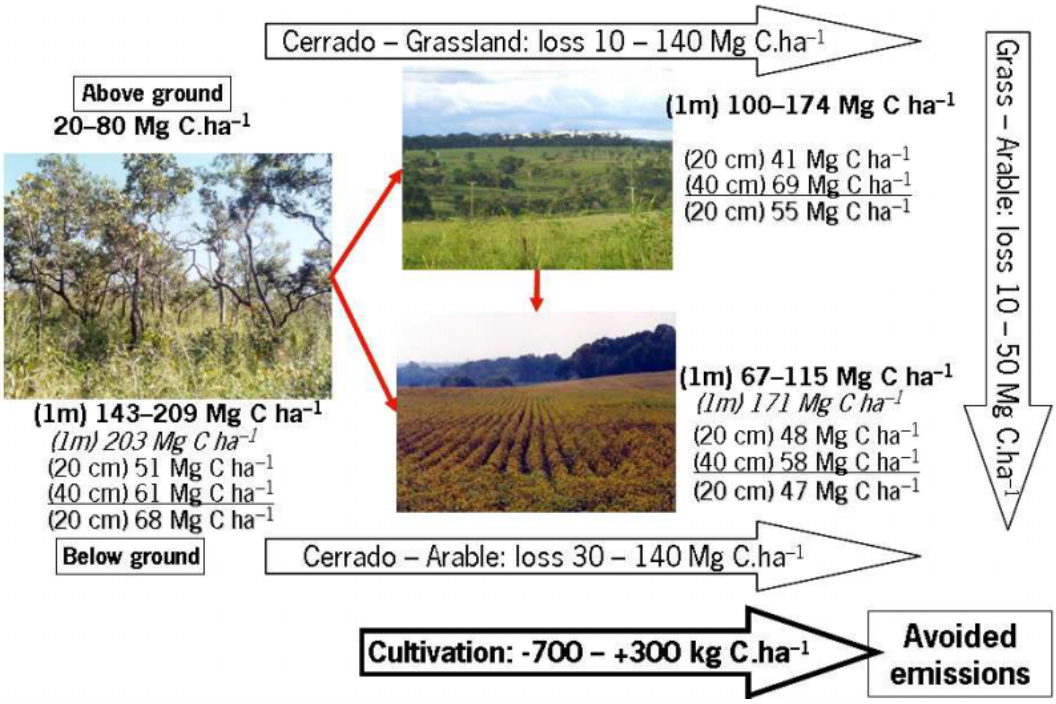

Figure 3.9. Above ground and belowground Carbon under different land use systems of the Cerrado. Numbers with same fonts are from the same reference. (bold - ; Italic Jantalia, 2007; Normal Freitas *et al.*, 2000; Underlined D'Andrea, 2004; Shadowed Cordeels, 2006).

Righelato and Spracklen (2007) have recently reported about the amount of carbon emissions that can be avoided (i.e. the CO_2 balance) for various crops. Direct savings, i.e. emission reductions, related to the growth and transport of a crop may be negative under poor agronomic management or reach positive values up to 3 tonnes $C.ha^{-1}$, depending on crop type. Losses of GHG due to land use change should, however, also be taken into account in the LCA's as the cultivation of any one hectare of crops for bio-fuels will claim additional land and cause the direct or indirect clearing of natural lands. These losses caused by the removal of vegetation and decomposition of soil organic matter may range from 30 for grasslands to over 350 tonnes $C.ha^{-1}$ for rainforests. It may henceforth take 20 to more than 150 years to recover the initial losses of CO_2-emissions (Fargione *et al.*, 2008; Searchinger *et al.*, 2008). Also, emissions of N_2O with a radiative forcing 296 time higher than CO_2, contributes to undo some of the potential CO_2 savings (Crutzen *et al*, 2007). Bio-fuels are therefore likely to worsen rather than solve climate change under these conditions. Tentative values for soybean in Brazil show carbon balances to range from -700 kg to +300 kg $C.ha^{-1}$ $season^{-1}$ while CO_2 losses due to (indirect) clearing of Cerrado lands range from 30 to 140 tonnes $C.ha^{-1}$, suggesting a payback time that might exceed 100 years, but could be as low as 15 years. Values of a same magnitude might be expected for the Chaco biome in Argentina where rapid expansion for soybean is taking place already.

4.3 Importance of land use and water planning

The quality of the land appears to have a large impact on the attainable yield levels. Also, clearing of natural lands for cultivation should be carefully selected as Cerrado soils are sensitive to erosion. Use of less suitable lands will lead to low yields and degradation of soils which in turn can result in the excessive and unnecessary clearing of natural lands. Proper planning taking into account these bio-physical aspects could prevent such unnecessary claims on natural lands areas. The example below illustrates the potential impact such a strategy could have.

Due to the low profits caused by the high exchange rate of the real and the low international soybean price in 2005/6 season, the cultivation acreage of soybean dropped in the season 2006/7. In the specific case of the state Mato Grosso, the acreage decreased from 5.8 (in 2005/6) to 5.0 million hectares, but yield increased from 2.7 t ha^{-1} in 2005/6 to 3.0 t ha^{-1} in 2006/7, with a modest impact of the rust epidemic that had not yet reached the area (CONAB, 2007). The yield increase is believed to result from the contraction of soybean cultivation area into the most fertile lands. This example illustrates the need for a systematic search as to what land areas could be used best for the cultivation of soybean in terms of bio-physical conditions. Generally factors other than these biophysical conditions drive the expansion of cultivation area, such as the vicinity to roads, markets, labour centres etc. By identifying suitable areas first and planning infrastructure to open up these regions, an impulse could be given to govern this process of land expansion. Proper planning is relevant also for minimizing GHG emissions of crop production.

Appropriate land use planning analyses should take into consideration the expected increase in demand for the most important food, feed and fuel commodities in Brazil. Soybean acreage will increase to meet the growing demand for food, feed and fuel. Even soybean is, however, facing fierce competition for land, but also water and nutrients with other agricultural activities, primarily sugarcane. The march of sugarcane for the production of ethanol is unstoppable and is already taking over best soils and regions with favourable rainfall. As sugarcane has to be produced within a radius of 50 to 70 km from a processing plant, it is already taking over with soybean and grazing lands. As a consequence soybean is pushed into more marginal regions and is in turn taking over grazing lands as well. The increasing national demand for meat in Brazil and the growing exports will put a claim on land as well. Maize and millet production may increase for meet feed demands. Land occupation may remain modest, however, if maize is grown as a second crop following soybean for instance. Whereas these crops are likely to expand in the Cerrado biome, expansion of area for palm oil is likely to occur in the Amazon biome (part 4).

5 Agricultural developments and land use change in the Cerrado

Modelling of water and biodiversity patterns are not available for the whole Cerrado region. However, at present we are analyzing available data for Mato Grosso and Goiás. Cardille and Foley (2003) already analysed the changes in the land cover of a part of the Cerrado for the period 1980-1995 (Figure 3.10, Table 3.4)

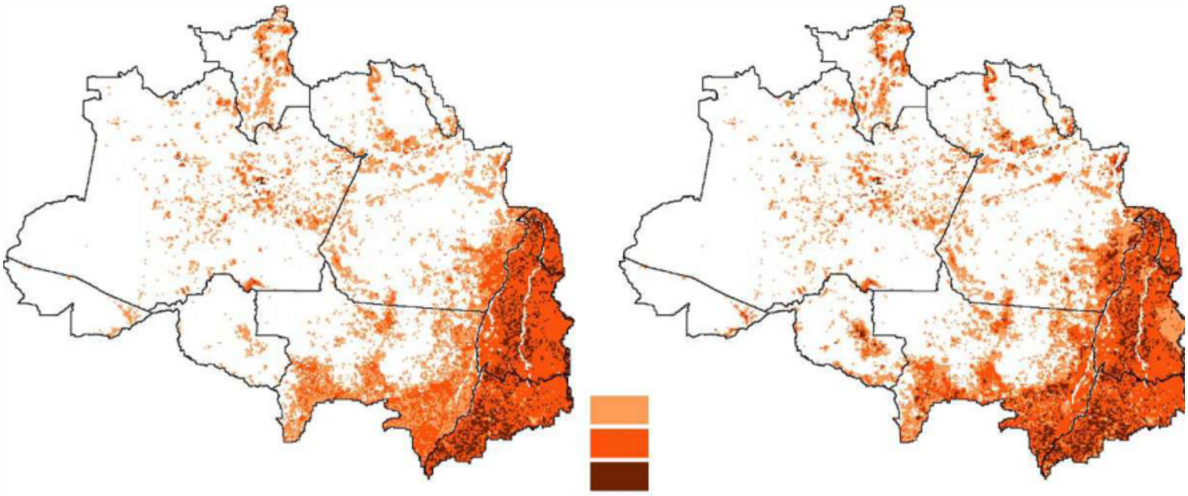

Figure 3.10. Changes in agricultural land use in Amazonian region, Brazil between 1980 and 1995 based on satellite and census data (Cardille and Foley 2003). White <10%, light: 10-30%, middle red: 30-60%, dark red >60% agricultural land.

Table 3.4. Changes in land cover in Goias and Mato Grosso between 1980 and 1995 (based on Cardile and Foley 2003); AG is Agricultural land.

	Cropland change (ha)	Natural pasture change (ha)	Planted pasture change (ha)	Total agricultural change (ha)	Total AG 1995/ total AG 1980
Mato Grosso	1.413.592	-2.769.445	6.028.897	4.673.043	1,50
Goiás	-635.735	-3.227.322	3.260.525	-602.531	0.94
Rondónia	16.970	99.829	956.958	1.073.757	2,93

In 2006 the Brazilian Ministry of Environment (MMA) made data available on land cover for the year 2002 that has been compared with available data form 2000. Because the legends were different a joint global legend has been made to compare between the two years. The legend that has been made consists of:

- Tropical forest (Amazonia and the gradient to the Cerrado);
- Cerradão and dense shrub Cerrado;
- Shrub and grassland cerrado;
- Agricultural land.

Based on these four categories a comparison has been made of the changes that have taken place. The situation in 2000 and 2002 is depicted in Figure 3.11. The changes between the 2000 and 2006 have been presented in Figure 3.12. In this figure the amount of changes in the last six years are presented in area and in intensity.

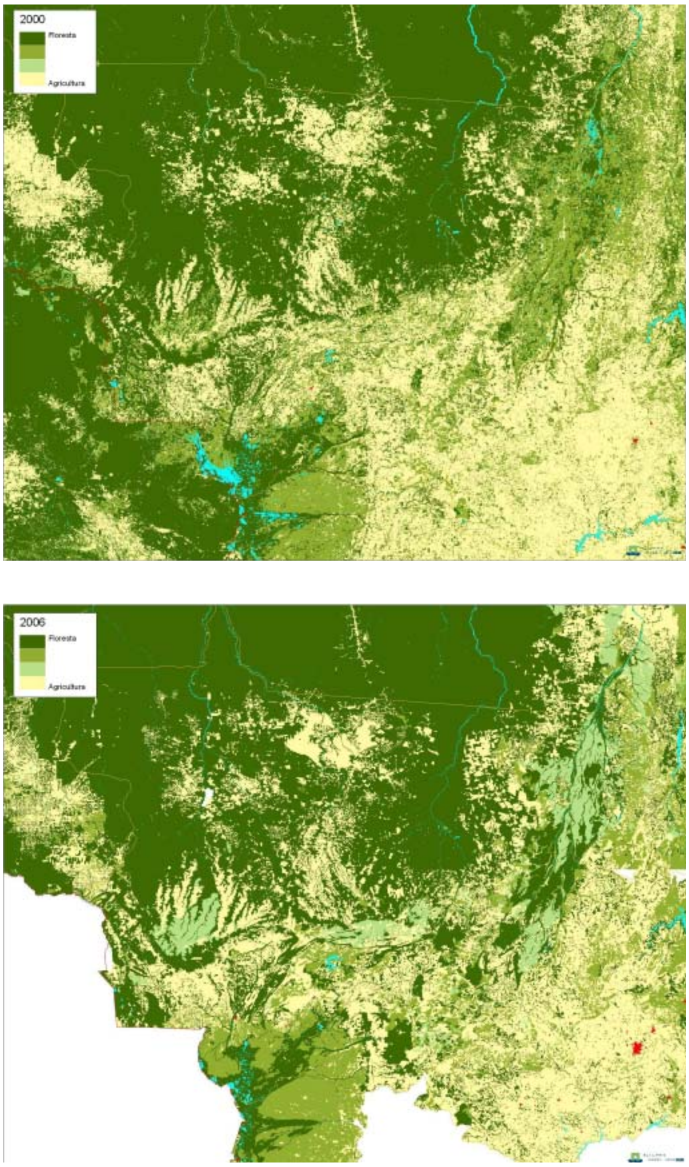

Figure 3.11. Situation of southern Cerrado (Mato Grosso, Goias) and Pantanal 2000 (top) and 2002 (bottom). Dark Green is tropical forest, Middle Green is Cerradão and dense shrub cerrado, light green is shrub cerrado and yellow is agricultural land.

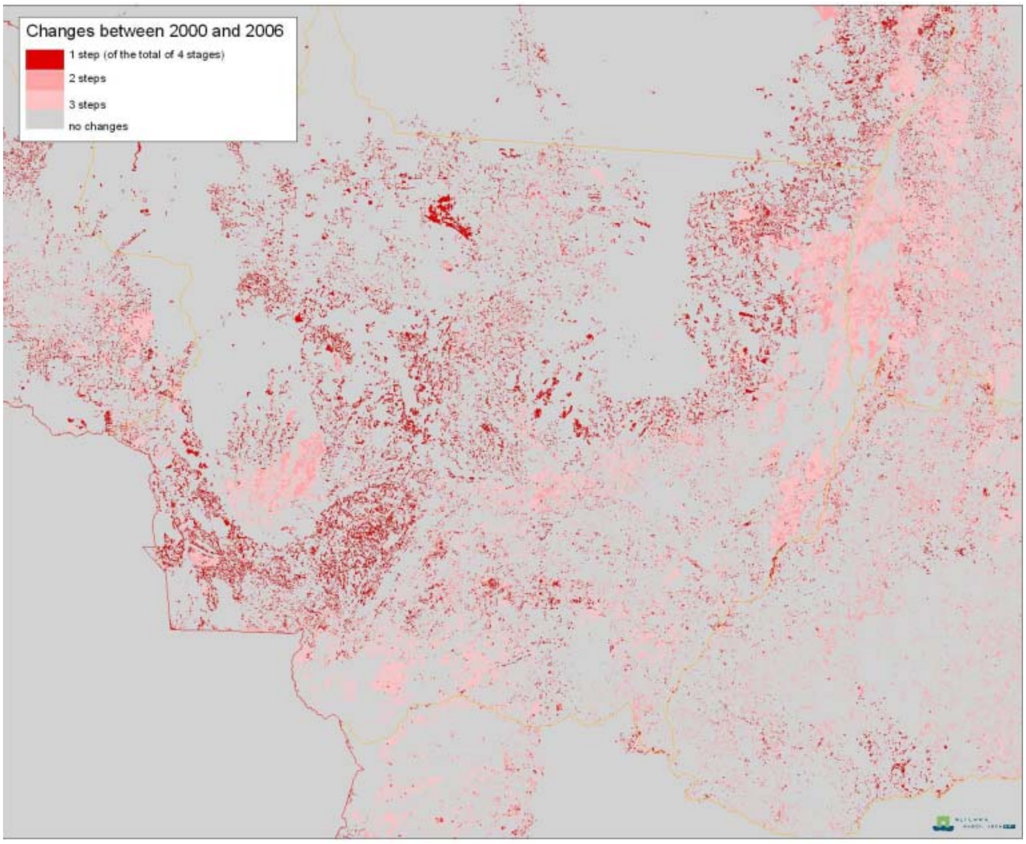

Figure 12. Changes in the Cerrado from one step (only one category change) to three steps (between four categories).

When comparing the two maps it can be stated, that there are significant differences between the two years 2000 and 2002. Because the maps have been made under responsibility of two different agencies it is not sure whether all differences are due to change; part will surely be caused by interpretation differences. For instance, the differences between the two years in tropical forest can be explained by interpretation differences. However, the differences in Cerradão might also indicate a change in land cover as does the trend that there is more degraded Cerrado and more agricultural land than in 2000. However, as this is a first interpretation without field check, conclusions must be made with care.

Table 3.5. Changes in land cover between 2000 and 2002 (see Figure 3.11). The change is not absolute as there are differences in area between the two maps.

	GLC Global Land cover, year 2000 (%)	**Probio, MMA data, year 2002 (%)**	**Estimated change (%)**
Tropical Forest	52.8	52.9	0.1
Cerradão/shrub cerrado	15.7	11.3	-4.4
Cerrado grassland	1.3	4.1	2.8
agricultural land	29.4	31.0	1.6
water	0.8	0.7	-0.1
urban	0.0	0.1	0.1
Total	100.0	100.0	

6 Perspectives, discussion and conclusions

Green House Gas Balance within the production chain

As discussed in part 3 and in part 4 the Green House Gas Balance of soybean and oil palm can be optimized compared to current practices. Savings in GHG emissions are feasible under optimal management practices and proper land use planning (see below). For soybean this may call for the cultivation of soybean in rotation with crops that need to be fertilized with nitrogen. Therefore, components of the inputs used in the second crop should be included in the GHG balance of soybean for a more complete balance. On the other hand, as discussed in part 1, not all losses can be fully accredited to soybean oil for the production of bio-diesel, as feed is a major output as well (80% of weight, 66% of energy and 60% of price). In this respect the allocation of GHG emissions to the oil (for energy) or to the protein cake (for feed) is very important. An allocation on the basis of price should will reflect the relative demand best and would be the most logical. For palm oil GHG savings are possible by preventing GHG emissions from wastes, efficient energy generation systems, recycling of nutrients and other measures such as proper land use planning (see below). The GHG balance demands which are being set by the EU (European Commission, 2008) plus the CO_2 tools being developed[12] to calculate this may help buyers of oil for biodiesel and producers to put measures into effect that indeed reach the GHG balance demands. The effort to do this should however not be underestimated and may add to the price of oil for biodiesel.

Direct and indirect land use change

Most problematic however is the (often indirect) clearing of new land for the cultivation of soybean or other perspective biodiesel crops. Sustainability is a sine qua non condition for biofuels promotion in the EU (Maniatis, 2008). Therefore biofuels will certainly have to contribute to a decrease in GHG emissions compared to fossil alternatives. A decoupling of crop production (for biofuel) from negative land use change is therefore absolutely necessary.

The CO_2 tools can take into account direct land use changes but indirect land use changes are not accounted for. Much carbon, both from above ground as well as from the soil is lost upon conversion of natural lands to grassland or cropland. These indirect or macro effects may make sustainable production of soybean for bio-diesel not to be feasible. Losses may be so high that it may take 20 to over 100 years to make up for these initial losses (see part 3). The Cramer Commission criteria have mentioned a maximal acceptable 10 year payback time. Though assessments of these indirect effects, focusing mainly on GHG, have been presented (see part 3) there is no consensus on how to assess this effect. As a result methods of accounting for this effect are not yet

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[12] http://www.senternovem.nl/gave/co2_tool/index.asp.

able to really reflect this. The ideas for decoupling soy (and other crop) production without increasing direct and indirect carbon losses due to land use change (mainly deforestation) have been discussed above (Chapter 4.2) and are also put forward by different entities in Brazil (see Abiove, 2008). As discussed this approach is centered around increasing the pasture use intensity by 10 to 20%, from less than 1 head of cattle now by integrating pasture and crop production in a kind of long term rotation scheme. Though the system could technically work the big question remains how implementation can take place and to what extent this development can release enough land both for additional food and feed production and for biofuels and thus isolate increased demand from deforestation.

Land use planning

Proper planning of land use is undoubtedly the most effective way to find optimal combinations for balancing the social, economic and environmental objectives that should be realised in the Cerrado and also in the Amazon region. It will remain unsatisfactory if maximization of one objective, e.g. maintaining all natural lands, would go at the expense of economic development. Explicit targets should be set and clear choices will have to be made to reach such optimal solutions. All these aspects on economic development through agricultural activities, maintenance of biodiversity and proper use of land and water resources towards most sustainable use of the natural resource base can be combined in land use analyses. While such analyses will reveal trade-offs between objectives, multi-stakeholder platforms should decide on priorities and on implementation strategies.

Other criteria

Further, other Cramer and EU criteria, such as loss of biodiversity, efficient use of water, will not be met under a business as usual scenario. No loss of valuable biodiversity is, for instance, accepted within these criteria. The biodiversity of the Cerrado is high and important for the South American continent. As there is a high ß diversity (diversity differences between regions) for conservation there will be a need for an analysis of hot spots and connectivity between hot spots. The best way to do so is that appropriate agencies and institutes will carry out a hot spot analysis and develop a conservation plan including landscape connectivity zones.

Due to development of agricultural production the water quality, the water discharge and erosion sediment load will change considerably. Sustainable land use means mitigation of these impacts. It is not possible to prevent eutrophication and erosion completely. However, lessons from the Taquarí case teach us that catchment based land and water planning and management is a prerequisite for high production and avoiding social conflicts between downstream and upstream users. Moreover, it can increase production per land unit and reduce unnecessary forest and savannah clearing.

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Part 4. Case study: Oil palm for biodiesel in Brazil. A different picture?

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Wolter Elbersen

1 Introduction

Oil palm (African Oil Palm, *Elaeis guineensis* jacq.*)* is the most productive oil producing plant available. In recent years oil palm has overtaken soy oil as the largest oil crop in the World with an annual production of more than 30 million ton. Due to its high yields and low cost of production oil palm is also considered a prime source of biodiesel production.

In 2003 the EU introduced the Biofuels Directive (2003/30) which aims at replacing 5,75% of transportation fuels by biobased transportation fuels such as biodiesel and ethanol in 2010. MVO (2006) estimates that by 2010 the EU rape oil production will be 9,9 million tons while the EU demand for biodiesel will be 11,1 million tons and the food demand will be 2,9 million tons. This will lead to a production shortfall of 3,8 millions tons of oil (for biodiesel) which has to be compensated by imports. Fediol estimates a shortfall of 4,5 million tons by 2010 (MVO, 2006).

Brazil is seen as a potential source of oils for biodiesel production for the EU. The Netherlands would be an important port of entry for this imported biodiesel (or vegetable oils). It is therefore of interest to investigate what options there are to import sustainably produced vegetable oils for production of biodiesel in the coming years.

In Brazil oil palm is seen as an interesting and sustainable crop for production of oil for biodiesel. In many countries, notably is Southeast Asia, oil palm expansion is associated with tropical forest destruction and consequently large scale biodiversity loss and large emissions of Green House Gasses. Together with concerns about social issues in the producing areas this has led to the RSPO initiative to guarantee the sustainability of palm oil production. The RSPO is an organization of stakeholders that has developed sustainability criteria for palm oil production. At the same time in the EU, The Netherlands, The UK and Germany there are initiatives to develop and introduce sustainability criteria specifically for biofuels (and bioenergy in general). The Green House Gas balance of production and the impact on carbon stocks (soil, forest, peat, etc) will be important criteria which determine whether biofuels are considered sustainable.

The first impression is that sustainability issues of palm oil production in Brazil are not viewed negatively in Brazil. In Brazil palm oil production is small and the crop appears to be viewed favorably by NGOs. It is claimed that palm oil plantations can be used to recover degraded lands in Amazonas of which there are many millions of hectares.

1.1 Objective

The objective of this review is to give an overview of Brazilian palm oil industry and the sustainability of Brazilian palm oil biodiesel production in the context of the worldwide debate on palm oil and the demand for biodiesel.

We will discuss the Brazilian biodiesel policies and demand shortly. Then give an overview of current palm oil production in Brazil and try to answer the question why oil palm such a small crop is at this moment. We will then discuss sustainability of palm oil production in Brazil in referring especially to Greenhouse gas criteria formulated by The Roundtable on Sustainable Biofuels (http://cgse.epfl.ch/page65660.html).

1.2 The Brazilian biodiesel policy

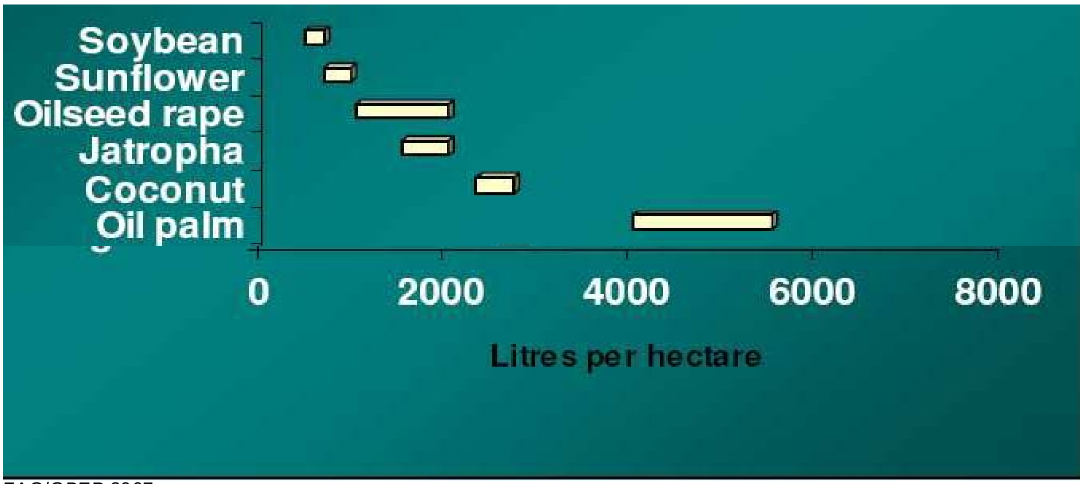
Brazil is well known for its ethanol production for replacement of gasoline. In the past 30 years it has developed and optimised this option and made it into an example for the rest of the world. The introduction of biodiesel to replace diesel has only started very recently. In 2004 Brazil launched the National Program of Production and Use of Biodiesel (PNPB) which is discussed in part 1, chapter 3.2.

Brazil introduced a mandatory blending law which mandates a 5% biodiesel blending in diesel in 2013, with an intermediary blend of 2% in 2008. This will require 840 million liters of biodiesel in 2008 and 2,4 billion liters of biodiesel in 2013 As Brazil intend to satisfy its own demand for biodiesel export options may be limited in the short run.

2 Palm oil in Brazil

The Brazilian biodiesel program has only started very recently and one of its main drivers is social (see also part 1). The main feedstock option for the short term is soy which has a 87% share in Brazilian vegetable oil production (in 2005). Still soy has to be considered mostly as a protein crop with less than 500 l of oil per ha per crop. There are some annual crops that may be used such as rape in the south, sunflower and castor (*Ricinus communis*). Still, these are often more expensive or limited in production potential. It is believed that perennial crops such as Jatropha and oil palm may offer higher yields and better returns. Palm oil may be a small crop in Brazil at the moment, it appears to have a large potential in Brazil. Furthermore knowledge of agronomic aspects and the total production chain is available making fast expansion possible. At this moment the only known biodiesel production from palm oil in Brazil is the at the Agroplama oil refinery in Belem which converts free fatty acids, which were previously not used, into biodiesel

Oil palm is the most productive oil crop currently available. Yields of 4 tons oil per ha per year are common under well managed conditions (see Figure 1). Yields of up to 8 tons of oil per ha are possible. It is no surprise that oil palm has become the leading oil crop in the world with an annual production of more than 30 million tons. Due to its high yields and low cost of production oil palm is also considered a prime source of biodiesel production.



FAO/GBEP 2007

Figure 4.1. Common oil yields for some important tropical oil crops.

Oil palm requires a average temperature between 24°and 28° C, precipitation (mm/yr): 1800 a 2000 mm/year and radiation of 1500 – 1800 hours/yr (Embrapa Amazonia Oriental). The range of adaptation in the World for palm oil is shown in Figure 2. Brazil probably has the largest potential area for palm oil production in the World. At the moment palm oil production is concentrated only in a few areas in the state of Para and near the Northeast Coast. Estimates of the actual area that is potentially available for palm oil production in Brazil ranges varies widely from 20 million ha as mentioned by Kaltner *et al*., 2005 to 7 million ha by Gazzoni, 2007. Kaltner *et al*. (2005) reports that some 3 million ha of degraded /altered land is available in the short run where basic infrastructure is available for palm oil production. This is necessary as oil palm requires processing within 24 hours of harvesting and needs a scale of more than 1000 ha of plantation area to be economically viable.

In all cases oil palm is seen as an option for recovering degraded and abandoned land. The land has been abandoned after clear cutting followed by production of crops and/or grazing for a few years without sufficient inputs leading to degradation. The factors leading to deforestation followed by unsustainable use common in the Amazon are complicated and involve government regulations and upholding them, human pressure, poverty, disputed land tenure, lack of lack of access to credit, etc. In this short study we cannot elaborate on this, though it clearly is of much importance if we want to determine the potential to produce palm oil for biodiesel in Brazil in a sustainable way.

In Table 4.1 current palm oil area, productivity and production of palm oil in Brazil is shown. It is clear that Agropalma and its associated producers is the dominant company in production of palm oil in Brazil. It also possesses the only palm oil refinery in Belem (PA). A larger share of young plantations (expansion, a lack of data and suboptimal production systems may explain the relatively low productivity of 2,58 tons per ha.

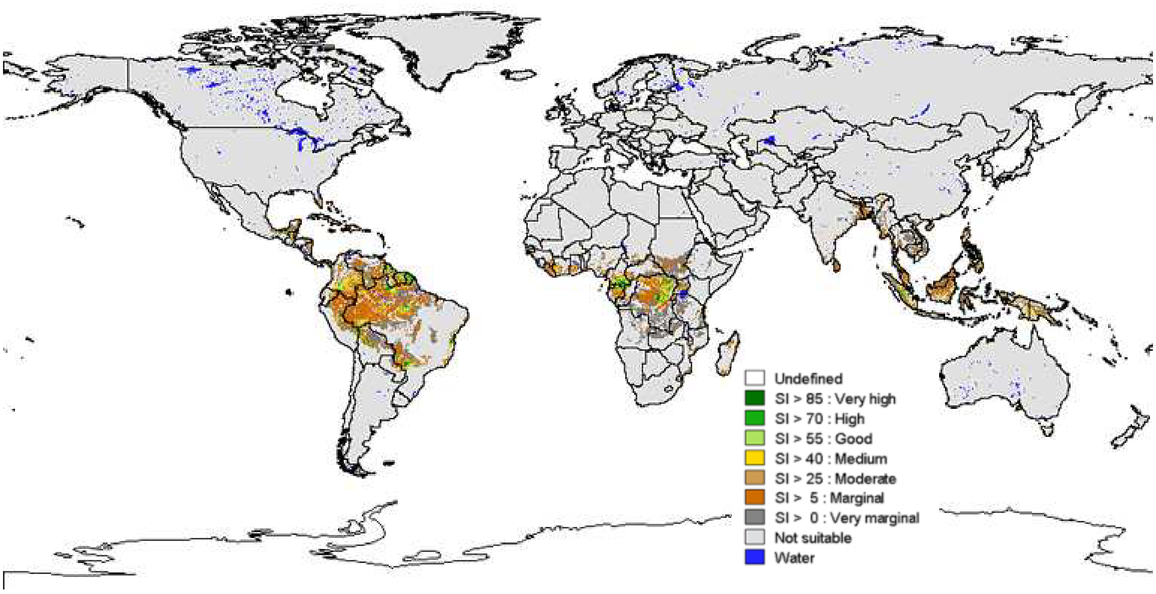


Figure 4.2. Land suitable for oil palm production in the world (IASA, 2000).

Table 4.1. Brazilian palm oil area, production and imports (Palmasa, 07/2007; http://www.neac.gov.my; FAOstat).

	2007 Area (ha)	**2007 Productivity ton oil/ha**	**2007 Production ton CPO+PKO***
Para			
Agropalma and dependent producers	33198	3.96	131400
Other producers (7)	20000	1.69	33850
Bahia	1400	?	9000
Amazonas	6510	?	?
Total	67453	2.58*	174250

* CPO=Crude Palm Oil, PKO = Palm Kernel Oil.

Despite the large potential production area, palm oil production in Brazil does not even cover local demand. At this moment Brazil is importing increasing amounts of palm oil. In 2005 39.000 tons CPO (crude palm oil) and 42.000 tons of PKO (palm kernel oil) were imported (*Palmasa, 07/2007; http://www.neac.gov.my; FAOstat).* The demand for trans-fat free products has increased demand for palm oil in Brazil.

Palm oil production cost estimates for Brazil have been made (Kaltner *et al.*, 2005). He reported production costs for palm oil in Brazil of just over $250,- per ton which was slightly higher than for soy oil in Brazil or palm oil in Indonesia and Malaysia. Still, the cost price of palm oil in Brazil appears only marginally higher than for soy oil or for palm oil produced in Southeast Asia.

2.1 Why is palm oil such a small crop in Brazil?

Brazil is a net importer of palm oil and palm oil products even though it has the largest area suitable for the cultivation of oil palm in the world (Figure 2). This strange contradiction begs the question why there is so little palm oil production in Brazil. In interviews with several people involved the following reasons were given for the very small area of palm oil plantations in Brazil:

- Most 'suitable areas' are still covered with natural vegetation – Only degraded areas should be considered an option for palm, limiting actually available land area.

- Soy is cheap to produce in Brazil and soy oil has until recently been very cheap because the soy protein has been the driver for production and export. This has made palm oil relatively uncompetitive compared to soy. Opportunity costs are high – other investments have a better return.

- Palm oil production is not a tradition in Brazil. Large scale production near Belem did not start until the 1970's.

- Land tenure in Para and many areas of Brazil is often unclear and can easily lead to land disputes. If the ownership of land on which a plantation has been established is disputed successfully a large investment is lost. This makes establishing palm oil plantations costly and potentially risky.

- Establishing a palm oil plantation requires a large investment which takes at least 4 to 5 years before it starts delivering revenues. This requires access to capital or loans which together with the risks are often not possible at a reasonable interest.

- Official labour costs were reported to be high compared to competing countries. Since Palm plantations require a large centralised organisation with a large work force official wages and costs have to be incurred.

- Not all the land owned can be used for palm production. Regulations exist that require 50 to 80% of land has to be maintained as forest) in the Amazon. As an example Agropalma owns >120.000 ha of land of which some 37.500 ha are planted with oil palm plantations. The other remaining area is managed as a forest reserve (adding to the total cost)

Palm oil offers the option for production of margarine without hydrogenation and production of trans fats. This has contributed to the demand for palm oil also in Brazil.

3 Sustainability of the Brazilian palm oil system

During a visit to Belem it was confirmed that palm oil plantations are generally viewed much more favourable by NGO's (personal communication Conservation International and Instituto Peabiru, November 1, 2007) than most other activities in the Amazon. Currently palm oil plantations are mostly limited to the large Agropalma plantation in Tailândia in the state of Para and a limited number of farmer cooperatives such as the one in Tome Acu. Generally NGO concern was mostly focused on illegal logging for timber and for charcoal production. Also cattle breeding and the pressure on land is seen as very negative. Expansion of palm oil plantations was not mentioned as problematic at the moment (November 2007).

At the end of 2007 it was observed that new large scale palm plantations were being implemented south of Belem. This was thought to be in view of the Brazilian demand for biodiesel which cannot depend on soy oil as local demand for biodiesel will increase to 2,4 billion litres of biodiesel per year in 2013.

In order to evaluate sustainability of biofuels criteria are being developed both nationally and internationally. (Cramer, 2006; The Roundtable on Sustainable Biofuels, 2007). These criteria are still under development and need to be operationalised.

Apart from the specific sustainability for biofuels the already mentioned RSPO criteria should be relevant. We should be able to assume that sustainability of palm oil is guaranteed if a plantation complies with RSPO sustainability criteria. These criteria have been established and are being implemented. Agropalma expected to be RSPO certified in 2008 (pers. Comm. Agropalma, 2007) as one of the first companies in the world. This would mean that most of the Brazilian palm oil could be RSPO certified in 2008.

Does that mean that Brazilian palm oil also is a sustainable biodiesel option?

3.1 Greenhouse effect of expansion of palm oil for biodiesel production

The most important difference between RSPO certification and Biofuels certification, which is being developed in Europe, (Cramer, 2006; The Roundtable on Sustainable Biofuels, 2007) is the demand for a positive GHG balance.

The Roundtable on Sustainable Biofuels (http://cgse.epfl.ch/page65660.html) has formulated the criteria on GHG effects as follows:

‘3. Biofuels shall contribute to climate stabilization by reducing GHG emissions as compared to fossil fuels. Emissions shall be estimated via a consistent approach to lifecycle assessment, with system boundaries from ‘root to tank’. This shall include direct and indirect GHG emissions, for instance from fossil energy used in growing, transporting and processing biofuels. It shall also include GHG emissions resulting from land use changes as land is converted to biofuel crop production, or as other production is displaced.’

In our opinion this means that we want to establish:
1. The GHG efficiency of the whole production chain. This includes the whole chain from field production to delivery of biodiesel to the consumer in Europe.
2. The GHG effect of land converted directly for the plantation.
3. The indirect GHG effect resulting from indirect competition for land and land conversions. This is also referred to as leakage.

With respect to 1, GHG efficiency of the whole chain; it has been proven sufficiently that palm oil production (for biodiesel) can have a very positive GHG balance. Fargione *et al.*, 2008 assume a GHG saving per ha of 7,1 tons of CO_2 per year when palm oil is used for biodiesel production. It is assumed that certain measures are taken in the production chain in order to avoid GHG emissions (Wicka *et al.*, 2007). They include utilising secondary by-products for powering the extraction plant, avoiding methane emissions from POME (palm oil mill effluent) and recycling nutrients to the fields (Elbersen *et al.*, 2005).
We observed that at the largest Agroplama FFB (fresh fruit bunch) processing plant in Thailandia by-products such as shells and fibre were being used for steam production for the processing plant and electric energy production. Anaerobic digestion of POME was or would become available. Empty fruit bunches were recycled to fields, thus returning nutrients to the plantation. This shows that at least at the largest FFB processing plant in Brazil requirements for a positive GHG balance (of the production chain) of palm oil biodiesel are largely in place.

With respect to 2, the GHG effect of land converted directly for the plantation; Current plantations have been converted from forest many years ago and we can assume that recent and future plantations have been or can be established on ‘degraded land’. The conversion of this degraded land will generally have a positive GHG effect within a relatively short period of time. This is also reported by Wicka *et al.* (2007) for conversion of degraded lands to palm oil plantations in Southeast Asia.

With respect to 3, the indirect GHG effect resulting from indirect competition for land and land conversions; things are not completely clear.

If palm oil from current plantations in Brazil is used for biodiesel production it will be in competition with food and other applications. This will likely result in more imports into Brazil of palm oil. Under the current high prices this is very likely to lead to expansion of palm oil production somewhere else in the world which is likely to lead to GHG effects which take many years to compensate for as is argued by Fargione el al (2008).

In order to avoid this, biodiesel should be produced on new palm oil plantation which have been established on degraded and otherwise not used land, as has been argued by Dehue (2005). This will take at least 5 years to give yields. As argued above (2) it should be possible in Brazil to establish these new plantations for biodiesel on 'degraded lands' avoiding unacceptable GHG emissions. Still long term conversion from 'degraded land' into palm oil plantation makes this land unavailable for 25 to 30 years. What would have been the use of these degraded lands in the coming 30 years? Could they have been upgraded for food production? Could it have accumulated biomass as a secondary forest?

Rules and regulations to protect the Amazon and rules and regulations that stimulate economic development are quite complicated and often counteract each other. An analysis of the rules, regulations and forces economic and social factor behind deforestation in the Amazon are far too complex to discuss in this short report.

3.2 Conclusions

Palm oil production is currently very small in Brazil. At the same time potentials are very large. Expansion on degraded lands should be possible in a sustainable way according to RSPO criteria.

The GHG balance of palm oil biodiesel should be considered positive if an unutilised by-products, such as free fatty acids, are used as a feedstock. Large scale dedicated production of biodiesel from palm oil will require establishment of new palm oil plantations if the GHG balance is to be positive. The direct effect of establishment of new palm oil plantations on degraded land should have a positive GHG balance if precautions are taken. Indirect (GHG) effects of the conversion of degraded lands in the Amazon into palm oil plantations are hard to predict and need to be evaluated in order determine if and how indirect GHG effects of using these lands can contribute to reducing GHG emissions in the long term compared to using fossil diesel.

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Appendix 1 Yield of common crops

Yields of common crops

Crop	kg oil/ha	litres oil/ha
corn (maize)	145	172
cashew nut	148	176
oats	183	217
lupine	195	232
kenaf	230	273
calendula	256	305
cotton	273	325
hemp	305	363
soybean	375	446
coffee	386	459
linseed (flax)	402	478
hazelnuts	405	482
euphorbia	440	524
pumpkin seed	449	534
coriander	450	536
mustard seed	481	572
camelina	490	583
sesame	585	696
safflower	655	779
rice	696	828
tung oil tree	790	940
sunflowers	800	952
cocoa (cacao)	863	1,026
peanuts	890	1,059
opium poppy	978	1,163
rapeseed (Canola)	1,000	1,190
olives	1,019	1,212
castor beans	1,188	1,413
pecan nuts	1,505	1,791
jojoba	1,528	1,818
jatropha	1,590	1,892
macadamia nuts	1,887	2,246
Brazil nuts	2,010	2,392
avocado	2,217	2,638
coconut	2,260	2,689

Crop	kg oil/ha	litres oil/ha
oil palm	5,000	5,950
Chinese tallow	5,500	6,545
Algae (actual yield)*	6,894	7,660
Algae (theoretical yield)**	39,916	47,500

* Actual biomass algae yields from field trials conducted during the NREL's aquatic species program, converted using the actual oil content of the algae species grown in the specific trials.[1]

** Algae yields are projected based on the sustainable average biomass yields of the NREL's aquatic species program, and an assumed oil content of 60%. Actual oil content was much less.[2]

- Note: Chinese tallow (Triadica Sebifera, or Sapium sebiferum) is also known as the 'Popcorn Tree' or Florida Aspen.

Source: Chinese tallow data, Mississippi State University.

Source: Used with permission from the The Global Petroleum Club.

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Appendix 2 Workshop report and Research Agenda Biodiesel from Brazil; Technology and sustainability

Date: 19 November 2007
Place: Ministry of LNV 'Laan van Nieuw Oost Indië' 131-133 in Den Haag, in room 008+010

Report made by:
Sarah Stattman
Wolter Elbersen

Background
De workshop is part of the project 'Quality and sustainability of bio-diesel for export from Brazil' that is being executed for the Ministry of Agriculture of The Netherlands. The Brazilian experience and export capabilities in ethanol are well known and have been analyzed extensively. Biodiesel is a relatively new option in Brazil. Only recently a biodiesel program has been set up which aims to replace 2 of diesel demand with biodiesel in 2010 and 5% in 2013. The ambition of the EU to is replace 5,75% of transportation fuels with biofuels. This will require 11,1 million tons of vegetable oil in 2010. This amount is expected to go beyond the production capacity of the EU and it is expected that there will be a shortfall of 3,9 to 4,4 million tons in 2010. Part of this shortfall could be filled by importing biodiesel from Brazil.
In this project we try to answer the question if and how it would be possible to import biodiesel from Brazil. We analyze both the technical issues and the sustainability issues involved. In the workshop we will be presenting our findings in 3 presentations (see below) and we have invited two Brazilian researchers to also give a presentation focusing on biodiesel development from a Brazilian perspective. Together with feedback from the experts attending the workshop we hope this will provide perspectives for importing biodiesel from Brazil in the coming years.

Program
- **Opening by Chairman Prof Pier Vellinga (WU).**
- **Wolter Elbersen (AFSG, Wageningen UR): Biodiesel in Brazil and options for export to The Netherlands: Mapping the Biodiesel chain.**
- **Rolf Blaauw (AFSG, Wageningen UR): How can Brazilian biodiesel comply with EU quality demands – now and in the future?**
- **Dr. Décio Luiz Gazzoni (EMBRAPA, Brazil)**
- **Prem Bindraban (PRI, Wageningen UR): Sustainability of biodiesel from Brazil with special focus on land use dynamics.**

- **Dr. Geraldo Stachetti Rodrigues (EMBRAPA, Brazil): Sustainability assessment of oleaginous crops for biodiesel in Brazil - viability of local productive arrangements.**

Presentations are available from: http://www.biomassandbioenergy.nl/biodieselbrazil.htm

General discussion statements

- Production of feedstock for Brazils own demand will be a challenge - Therefore export potential appears limited in the short and middle term (2010 – 2015)
- Sustainability discussion in Brazil focuses more on social and biodiversity issues less on GHG effects
- Indirect effects of feedstock production on GHG emission and other sustainability criteria is more important than the direct effects (in the chain) and should be included in European standards
- Any additional production of feedstock will go at the expense of natural areas, as grassland productivity increase is (currently) not likely to alleviate land demand
- Optimal agronomic management is needed for any agricultural system, irrespective of the use of the produce (food, feed or fuel). i.e. sustainable production is as relevant for all production.
- For the coming 5 to 10 years soybean will be the main supplier of biodiesel
- GHG balances are hardly an issues (in Brazil). Data for GHG calculations is mostly lacking
- Sustainability demand and criteria could:
    - Support use of by-products
    - Provide incentive against negative land use changes
- 'Ethanol is a product. Biodiesel is a project'
- Biodiesel is important for local and regional security of supply giving it a direct advantage over fossil fuel

Discussion statements by Chairman Pier Vellinga

- Soybean is likely to be a major crop for biodiesel production until 2020
- There are three major environmental concerns: net-carbon results, biodiversity conversions, and required inputs.
- Brazilian researchers are vary capable, they have the capacity to meet international consumer concerns

Discussion issues

The first discussion issue was dealing with calculations of the C balance in the GHG equation. Issues that came forward considered:

- When you attribute the results of deforestation to energy demand than you do not start with a negative balance.
- It would be possible to reduce C when charcoal is already taken out of the equation, but it would still be different if you would convert from grassland (than the problem of biodiversity loss remains).
- A stereotypical assessment is as follows: forests are cut for wood, than they develop into grasslands, when these are degraded annual crops like soy are planted.
- The main question is how to set up a baseline? For example 100% of Brazilian steel production is based on charcoal this is more sustainable for GHG than coal. Yet it does not resolve the problem of biodiversity losses.
- We should consider the whole range of emissions that are already taking place, rather than to look at case independently.

The second issue regards land transformation. What is the size of the companies that are involved, how do they improve productivity and is it possible to speak of land use planning?

- Brazilians have the feeling they are at the start of a agrarian revolution. Currently there is a large increase in the net-income of families, this is a quick change. Planning for a short time frame is possible, but a long term perspective is difficult, because so many demands are increasing simultaneously. The question also regards profitability of: sugarcane, soy and grass and the development of meat export. Currently it seems that sugarcane and soy are pushing the grasslands toward the boarders of Brazil. This will lead to the problem of increased transportation costs for the meat sector. This could lead to more efficiency, but it is difficult to predict because of the period of instability.
- In general, land use planning only takes place on the local scale. There is no holistic country wide approach.

Possible Research Question

- Do we need a more systematic land-use planning system?
- How should such a system be set-up?

The third issue regards the question whether or not productivity on grasslands will increase.

- Currently there are 180 million heads of bovine in Brazil, they occupy 200.000 million ha of grassland. This means there is only 1.9 head/ha. By just using the grasslands a little more efficient for example a 10% increase in 10 years this would already release a large amount of hectares.

Possible Research Questions

- *Is the driver for productivity increase just based on profitability?*
- *When the cattle areas is pushed towards the border, will the industry be more cost efficient in order to cope with higher production costs?*

The fourth issue regards the question representation of e.g. EU consumers regarding the Brazilian Amazon.

- Often the media presents images of bad exploration and deforestation in the Amazon region. The Brazilian government should spend money in order to convince people that the stories we are told on television is not an actual representation.
- There are many initiatives such as the RTRS, Soybean 4000, etc. how should we evaluate these initiatives and make sense of them?

Possible Research Question

- *How does the view of the economic use of the Amazon influence trade opportunities?*
- *How can a useful dialogue be set-up?*

The fifth issue regards the competition between soybean and sugarcane.

- The problems with sugarcane are quite confined. In the 1970s it was easy to expand, but under pressure of the authorities and public opinion very strict legislation has been set up for plants. It is not easy to expand, increase production, build new plants, etc.
- Sugarcane (for ethanol) only occupies approx. 3 million ha. This is a small area for Brazil. This is mainly due to the high efficiency which results in up to 8000 l Ethanol per ha.
- Yet in this respect there are questions of land values versus income generation.

Possible Research Question

- *What are the sustainability issues concerning sugar cane (for ethanol) expansion from a Brazilian and an EU (NL) standpoint?*

The sixth issue regards the availability of standards for biofuel and/or possible certificates.

Possible Research Question

The seventh issue regards the complexity of all demand of Food, Feed and Fuel issues. Not only on the scale of Brazil but on an international scale. What are the theories versus practical implication issues of GHG balances?

- The question whether or not biodiesel should be used is already answered. The discussion should regard the way forward i.e. how to implement policies in a sustainable way?
- One of the issues is how to measure the indirect effects of land use change, maybe it is possible to turn this question around and ask: what happens if we order one extra ton?
- Not only land use change needs to be considered, but also issues as land management.
- Possible Research Question: is it an option to use ecological-economic zoning to measure indirect effects?

The eight issue regards the topic of scarcity. What would happen if Brazil would not sell to the EU.

- The green fuels are an alternative, but they could only replace 20% of fossil fuels based on.
- From a Brazilian point of view it is important to have an improved control on market prices. Increased commodity prices due to increased demand is the most positive environment impact on Brazil that is possible. Unfair subsidies have always been the worst problem for good nature conservation. It does not pay to invest in preservation when commodities do not pay well, when their value increases so does the value of the land.

Possible Research Question

- *Do* increasing commodity prices result in better and more efficient land management in *Brazil?*

Setting up a research agenda

1. Forecasting, modeling, 2nd generation

- Make analysis of FFF – flex markets; use of soy for different purposes.
- How to model forecasts of vegetable oil, bio-diesel according to various feedstock demands i.e. policy development or strategic actions?
- Establishing present status and future perspectives of converting biomass to 2nd generation biofuels. (When? What impact?)

- To what extend does the demand for bio-diesel lead to changes in landownership and contractual relationships?

2. Zoning/planning

- How and under what mechanism can grassland productivity be increased such as to alleviate the demand for land for arable crops?
- How to model the process of land use dynamics in the Cerrado region/Amazon and its impact on C, GHG, water, and social stability?
- How can agro-economic zoning help to comply with legal realities?

3. GHG measurements

- We need good data for GHG calculations: land conversion, the indirect effects that need to be included in the calculation.
- What is a baseline for GHG measurements?
- Possible indirect effects of feedstock production on GHG and other sustainability variables which are more important than the direct effects which could be included in EU certification.

4. Technical concepts in processing

- How do soy farmers/producers cope with environmental standards, how can we learn from this when we move on to bio fuel standards? (making laws vs. Living according to the law)
- Will the engine of diesel cars be adapted to developments in the bio diesel market? (modification of the engine and/or of bio diesel in 1st generation)
- How to better deal with trade-offs related to intensification and productivity in a diversified setting?

5. Sustainability indicators and assessment

- How to create measurable sustainability indicators?
- How can Brazilian companies certify according to the Cramer criteria?
- How to translate the general sustainability criteria into local/national standards/priorities?
- How do we perceive sustainability vs. The way it is perceived in Brazil? (eg in EU - production areas -> also relates to certification)
- Can you quantify the sustainability effects of broad vs. Narrow bio fuel standards?
- Testing the social stamp (small farmers, various crops, regions) > does it work on the long run as a way to promote sustainable development?

6. Governance, multi stakeholders, legislation

- Structure of corporate industry: What are the implications of the changing of this market for soy traders (corporate business) for sustainability criteria? (criteria / actors in the chain -> the way production is organised will determine who profits)
- How can local communities benefit (are already benefiting) from bio fuel production? What mechanisms are needed?
- What is the impact of Roundtable initiatives for the management of e.g. bio fuel/soy?

7. Production ecological principles

- To what extend can integrated crop-animal systems contribute to more sustainable production systems?
- Brazil should have an opinion on the way LCA can allocate CO_2 equivalents to different products
- Analysis of the patterns of biodiversity and environmentally sensitive areas and scenarios for sustainable land use, biodiversity and land conservation.

8. Trade issues, logistics

- How is the soy and bio fuel market organised?
- How will quality standards vs. Trade regulations influence each other? (what is the use of global bio fuel standards)
- How are commodity prices increased impacting productive and conservation practices?
- What happens with by-products such as glycerol/protein? New markets?
- Could you vary the mix of bio fuels to stabilise market prices?
- Is it possible to make the end-consumer pay extra for sustainable products? How?
- What can we learn from the crude oil market regarding issues of standardisation? Pricing in accordance to quality – oil labels/brands

9. Other topics

- (integrated) Bio-refinery concepts – What opportunities exist to make better use of existing biomass streams by integrated production of energy, products, chemicals, feed and fuel?
- comparison of bio-fuel to other forms of renewable energy – i.e. second generation fuels will require biomass that is also used for electricity and heat production
- Who is willing to support technological research regarding sustainable production systems? EU funding?
- General study on how to change consumer behaviour in relation to sustainability.