Global Assessment of Biomass and Bioproduct Impacts
on Socio-economics and Sustainability

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Report on Show Cases and linkage of environmental impacts to socio-economic impacts (D 5.3)

WP 5 – Task 5.4

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Authors: Nils Rettenmaier, ifeu – Institut für Energie- und Umweltforschung Heidelberg GmbH, Germany
Achim Schorb, ifeu – Institut für Energie- und Umweltforschung Heidelberg GmbH, Germany
Gunnar Hienz, ifeu – Institut für Energie- und Umweltforschung Heidelberg GmbH, Germany
Rocio Diaz-Chavez, Imperial College, United Kingdom

Editors: Nils Rettenmaier, ifeu – Institut für Energie- und Umweltforschung Heidelberg GmbH, Germany

Contact: ifeu – Institut für Energie- und Umweltforschung Heidelberg GmbH
Nils Rettenmaier
E-mail: nils.rettenmaier@ifeu.de, Tel: +49 6221 4767-24
Wilckensstr. 3
69120 Heidelberg, Germany
www.ifeu.de

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Abbreviations

CO_2 Carbon dioxide

CPO Crude palm oil

EC European Commission

ESP Energy service platform

EU European Union

FAME Fatty acid methyl ester (biodiesel)

FFB Fresh fruit bunch

FSC Forest Stewardship Council

GEF Global Environment Facility

GHG Greenhouse gas

GM Genetically modified

HCV High conservation value

iLUC Indirect land-use change

ISCC International Sustainability & Carbon Certification

JME Jatropha oil methyl ester (Jatropha biodiesel)

LCA Life cycle assessment

MJ Megajoule (10^6 joule)

NG Natural gas

POME Palm oil mill effluent

RED European Renewable Energy Directive (2009/28/EC)

SJO Straight Jatropha oil

SWOT Strengths, weaknesses, opportunities & threats

US United States (of America)

Preface

This report was elaborated in the framework of the Global-Bio-Pact project (Global Assessment of Biomass and Bioproduct Impacts on Socio-economics and Sustainability) which is supported by the European Commission's 7th Framework Programme for Research (FP7).

The main aim of Global-Bio-Pact is the improvement and harmonisation of global sustainability certification systems for biomass production, conversion systems and trade in order to prevent negative socio-economic impacts. A number of sustainability certification systems are already in place, but their main focus up to now is on environmental impacts such as greenhouse gas emissions or biodiversity.

A core activity of Global-Bio-Pact is the description of socio-economic impacts in different countries to collect practical experience about socio-economic impacts of biofuels and bioproducts under different environmental, legal, social, and economic framework conditions. Despite its focus on socio-economic impacts, the project also looked into selected environmental impacts such as greenhouse effect (global warming), biodiversity, water and soil. Ideally, socio-economic and environmental impacts would be positively correlated. However, in some cases biomass production may create positive social impacts, but negative environmental impacts, and vice versa. It is important to identify those trade-offs, but also positive and negative correlations.

This report presents the observed linkages between socio-economic and environmental impacts based on an analysis of Strengths (S), Weaknesses (W), Opportunities (O) and Threats (T).

1 Introduction

Within the Global-Bio-Pact project, the objective of work package 5 (WP 5) is to identify hotspots of trade-offs and correlations between socio-economic and environmental impacts of biomass production in developing countries. Based upon the assessment of existing studies and the results of WP 2 and 3, WP 5 is investigating the linkages between major environmental and socio-economic impacts of biofuel and bioproduct life cycles. This is important since positive social impacts are not necessarily associated with positive environmental impacts, and vice versa.

The aim of this report is to reveal trade-offs as well as positive and negative correlations between socio-economic and environmental impacts. This way, opportunities to minimise negative and optimise positive impacts on both the environment as well as social and economic situations will be identified. After a brief overview on general linkages between socio-economic and environmental impacts (chapter 2), the results of the SWOT analyses (analysis of strengths, weaknesses, opportunities and threats) are presented for each of the seven Global-Bio-Pact case studies in chapter 3. Each SWOT analysis starts with a brief description of the case study, followed by a section on environmental and socio-economic impacts, respectively. Finally, trade-offs as well as positive and negative correlations between socio-economic and environmental impacts are identified. Chapter 4 summarises the findings in a synopsis.

All information regarding environmental and socio-economic impacts used for the SWOT analyses was entirely obtained from the Global-Bio-Pact case study reports. However, the views expressed in this document by IFEU and Imperial College are the sole responsibility of the authors who have aggregated and condensed the information. They do not necessarily reflect the views of the entire Global-Bio-Pact consortium. For in-depth insights and a more comprehensive picture on the situation in each of the countries, the reader is referred to the original case study reports.

2 General linkages between environmental and socio-economic aspects

Since “the environment” actually means soil- to grow food; water- to drink, wash and irrigate crops; and air- to breathe, and a host of natural food and medicinal products, it becomes clear that preserving “the environment” actually means safeguarding food production, sustaining livelihoods and preserving health. Poverty reduction, economic growth and the maintenance of life-supporting environmental resources are therefore inextricably linked (OECD 2001).

According to UNECA (2008), the pursuit of environmental sustainability is an essential part of the global effort to reduce poverty, because environmental degradation is inextricably and causally linked to problems of poverty, hunger, gender inequality, and health. Livelihood strategies and food security of the poor often depend directly on functioning ecosystems and the diversity of goods and ecological services they provide.

The concept of ecosystem services as well as the so-called areas of protection link environmental and socio-economic aspects. They are both shortly introduced in the following.

Ecosystem services

Ecosystem services are the benefits people obtain from ecosystems. These include provisioning, regulating, and cultural services that directly affect people and supporting services needed to maintain the other services. Changes in these services affect human well-being through impacts on security, the necessary material for a good life, health, and social and cultural relations (Millennium Ecosystem Assessment 2003). Fig. 2-1 shows the linkages between ecosystem services and human well-being.

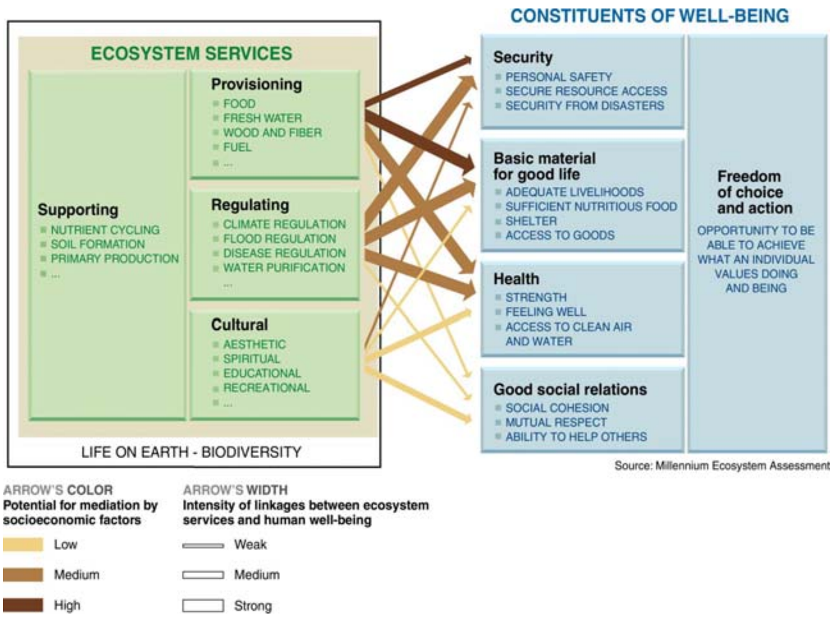

Fig. 2-1 Linkages between ecosystem services and human well-being. (Millennium Ecosystem Assessment 2005)

Areas of protection

Life cycle assessment (LCA) addresses the environmental aspects and potential environmental impacts (e.g. use of resources and the environmental consequences of releases) throughout a product's life cycle. There are two methodological approaches which either translate impacts into environmental themes such as climate change, acidification, or human toxicity (problem-oriented or midpoint approach) or into issues of concern such as human health, natural environment, and natural resources (damage-oriented or endpoint approach) (see chapter 6.1 and Rettenmaier et al. 2011).

These issues of concern are referred to as areas of protection (Table 2-1) or safeguard objects. The definition of what constitutes an area of protection is mainly determined by a society's basic moral and ethical values, as well as the ethical values of the individuals who make this determination. According to de Haes et al. (1999a), these areas of protection include impacts on **human health** (release of toxic substances, emission of photo-oxidants and ozone-depleting gases), on the **natural environment** (release of toxic substances, emission of acidifying and eutrophying gases, land-use impacts), on natural **resources** (non-renewable energy carriers and minerals) and on **man-made environment**. The first and the last one clearly demonstrate the link between environmental and socio-economic aspects.

Table 2-1 Overview of the relevant areas of protection and main societal values connected to them /de Haes et al. 1999a/

Areas of protection:	**Societal values:**
1. Human health (HH)	intrinsic value of human life, economic value
2. Natural environment (NE)	intrinsic value of nature (ecosystems, species), economic value of life support functions
3. Natural resources (NR)	economic and intrinsic values
4. Man-made environment (MME)	cultural, economic and intrinsic values

Likewise, an environmental impact assessment (EIA) shall identify, describe and assess in an appropriate manner, the direct and indirect effects of a project on the following factors:

- human beings, fauna and flora;
- soil, water, air, climate and the landscape;
- material assets and the cultural heritage;
- the interaction between the factors mentioned in the first, second and third indents.

Also here, human beings are mentioned in the first place, underlining the fact that one of the main motivations behind environmental protection is human health.

3 SWOT analyses on case studies

This chapter comprises a short introduction into the methodology of SWOT analysis, the characteristics of the case studies and the procedure of data collection. Subsequently, it identifies the linkages of the environmental and socio-economic aspects for each case study.

3.1 Introduction to SWOT analysis methodology

A SWOT analysis is a tool to assess the performance of a project, a product or a company. It originates from business management and it is a strategic planning tool to identify and assess the Strengths (S), Weaknesses (W), Opportunities (O) and Threats (T) of the surveyed project, product or company. In the Global-Bio-Pact project, the different cases studies were analysed using SWOT analysis methodology. This way, differences in the biomass production and conversion into the biofuels and bioproducts depending on specific environmental, social and economic conditions are revealed.

Favourable and unfavourable internal factors which are determined by the product itself are classified as Strengths (S) and Weaknesses (W), respectively. Regarding external factors such as competing products, markets and political / institutional influences, a distinction is made between Opportunities (O) and Threats (T), depending on whether they are favourable (O) or not (T). The general structure of a SWOT matrix is shown in Fig. 3-1.

	Favourable	Unfavourable
Internal	**Strengths**	**Weaknesses**
External	**Opportunities**	**Threats**

Fig. 3-1 Structure of a SWOT matrix

For marketable products, a distinction between internal (only influenced by the evaluated product, i.e. absolute) and external factors (aspects only influenced by competing products or markets, i.e. relative) is simple. However, the application of SWOT analysis on environmental and socio-economic questions is not straight-forward with regard to system boundaries and definitions. Therefore, the following adjustments are made regarding the definition of internal and external factors: Opportunities are defined as strengths of the future and threats are defined as weaknesses of the future. This definition is adapted for the following reason: whether an opportunity becomes a strength is depending on political, technological, economic, social and environmental developments. These external factors are not influenced by the value chains as they are implemented today in the case study regions. The same holds for threats and weaknesses. In addition to time, there are no other clear system boundaries, since the success or failure of biomass cultivation and processing is highly related to the political and geographical circumstances.

3.2 Data collection and identification of linkages

Within the Global-Bio-Pact project, seven case studies have investigated the socio-economic impacts of the biomass production and conversion into biofuels and bioproducts. Six of them have also looked into environmental impacts. In each of these case studies, three different geographical scales were assessed: the national level, the regional level and the local level. Each of them was selected in order to identify and reveal characteristic issues associated with the feedstock production on the different geographical scales.

Within the case study reports, several aspects were investigated in order to assess both the environmental and the socio-economic impacts of biomass production and conversion.

Regarding the **environmental impacts** the following issues were discussed:

- Biodiversity
- Water resources and water quality
- Soil
- (Greenhouse gas emissions)

The latter issue, greenhouse gas emissions, was dealt with in Task 5.2. The results of the greenhouse gas balances can be found in the annex of this report (chapter 6). The calculations were done by IFEU based on the case study data provided by the project partners. Apparently, land-use changes after 01/01/2008 were not observed in any of the case studies.

Provided that detailed information was available, the assessment of the **socio-economic impacts** distinguishes between impacts associated with biomass production and impacts associated with biomass conversion. The following aspects are considered:

- Economics
- Employment generation
- Working conditions
- Health issues
- Food issues
- Land-use competition and conflicts
- Gender issues
- Other issues identified as important by the authors of the respective case study reports

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Regarding the identification of linkages between socio-economic and environmental impacts the following classification was applied (see also Fig. 3-2**)**:

- Positive and negative correlations, respectively, were identified, if both aspects showed the same tendency regarding the observed impacts
  - o both positive ('+ +'; positive correlation, 'win-win situation') or
  - o both negative ('- -'; negative correlation, 'lose-lose situation').
- Trade-offs were identified, if both aspects showed opposite tendencies regarding the observed impacts
  - o one positive and the other negative ('+ -') or
  - o one negative and the other positive ('- +').

Positive correlation	**+** **+**	**-** **+**	Trade-off
Trade-off	**+** **-**	**-** **-**	Negative correlation

Fig. 3-2 Classification of linkages between socio-economic and environmental impacts

Please observe that in the above mentioned context, 'correlation' by no means implies any causal relation. It simply describes a relation existing between phenomena or things which tend to vary, be associated, or occur together in a way not expected on the basis of chance alone.

3.3 Results of SWOT analysis on case study Argentina

After a short description of the case study the results of the SWOT analysis on the environmental and on the socio-economic aspects associated with the production of soybean oil biodiesel in Argentina are presented. Finally, the linkages between the environmental and the socio-economic aspects are identified and discussed.

3.3.1 Description of case study

Continent:	South America (South-East)
Country:	Argentina
Climate region:	Warm temperate, dry
Soil type:	High activity clay
Feedstock source:	Soy(bean)
Product:	Biodiesel
Case study at national level:	Biodiesel from soybean oil in Argentina. In 2008/09, soybean was cultivated on 18 million hectares (about 56 % of all arable land).
Case study at regional level:	Two different case study regions with different eco-systems; one in the central productive area of Argentina producing around 85 % of Argentina's soybean yield, the other one a growing new area in the north part of the country
Case study at local level:	not conducted; see *Special remarks*
Special remarks	Since the agricultural production systems are too large to be investigated at local level, two case studies at regional level were surveyed. Soybean cultivation has long since been implemented in the Argentine economy. In contrast, the production of biodiesel has only been initiated in broad-scale around 2006. Therefore, the influence of the biodiesel production on the observed changes brought along by the cultivation of soybean was hard to assess. Assuming that the implementation of biodiesel did not result in more soybean cultivation, but rather in a redistribution of soy between different sectors, the impacts are solely connected to the conversion plants. These aspects, though, can be assumed as being insignificant compared to the impact of the cultivation of soybean.

3.3.2 Environmental impacts

Fig. 3-3 shows the SWOT matrix regarding the environmental impacts of biodiesel from soybean oil in Argentina. Both the observed strengths and weaknesses are mainly to be allocated to the advanced, large-scale and high-input soybean cultivation as a whole rather than to the use of soybean oil as a feedstock for biodiesel production.

Soil compaction for example – observed on certain soil types within the country and reported as a weakness - is a result of the high degree of mechanization (use of technical equipment such as heavy farming machinery) in soybean cultivation. However, so far soil compaction didn't have any negative impact on yields. The loss of soil fertility is due to the insufficient replenishment of macro and micro nutrients in the soil. As a consequence, fertilizer use has increased over the past ten years.

The reduction of greenhouse gas emissions compared to the fossil reference fuel and the positive impact regarding soil erosion were identified as strengths. The latter aspect is due to the so-called no-tillage farming system which was introduced in Argentina in the late 1980s (today adopted by approximately 85 % of the farmers), mainly because it reduces soil erosion and soil water evaporation. However, today's no-tillage system is linked to the cultivation of transgenic herbicide-resistant soybean which was started in the mid 1990s (today over 70 % of Argentina's production is GM soybean). This combination of no-tillage farming and cultivation of GM crops is accompanied by an increasing use of non-selective, broad-spectrum herbicides such as glyphosate, which might have severe environmental impacts on biodiversity, water and soil (Greenpeace 2011).

• greenhouse gas emission savings of almost 60 % compared to the fossil reference fuel (75 % - 85 % if improved agricultural management would be taken into account), see chapter 6.2.1 for details • risk of soil erosion has decreased over the last 20 years due to introduction of no-tillage system	• increasing need to apply fertilizer as indicator of decreasing soil fertility • soil compaction on certain soil types • in the North region, 500,000 ha of sub-tropical dry forest were deforested for soybean production between 1998 and 2002.
• no opportunities reported	• one case study is located in a region with high concentration of non-commercial forest indicating danger of expansion to highly biodiverse areas • severe environmental impacts due to herbicide use associated with GM soybean cultivation

Fig. 3-3 SWOT matrix for the environmental impacts of the production of biodiesel from soybean oil in Argentina (IFEU & IC based on Sbarra & Hilbert 2011)

A major weakness to be mentioned are the direct land-use changes: in the North region, 500,000 ha of sub-tropical dry forest were deforested for soybean production between 1998 and 2002. One of the case studies, Viluco, is situated in this region (Santiago del Estero province). During this period, land-use changes were rather linked to the general expansion of the soybean cultivation area (for animal feed production) than to biodiesel production, i.e. the expansion was mainly driven by soybean meal production with soybean oil being a co-product. According to the case study report authors, large-scale soybean oil biodiesel production only started after this period. Clearing pristine forest areas can cause massive greenhouse gas emissions and losses of biodiversity. This aspect was pointed out in the case study report, too, since one of the case studies might expand into non-commercial forests and thereby threatens areas with high conservation value.

3.3.3 Socio-economic impacts

The SWOT matrix regarding the socio-economic impacts only contains few aspects. This is due to the difficulty of differentiating between the impacts of biodiesel production from soybean oil (a co-product of soybean meal production) and the general impacts of the agricultural system (see Fig. 3-4). The **economic** aspects show clear strengths regarding the past development of the biodiesel sector, i.e. huge increase of the biodiesel exports in the last years. Also great prospects were observed regarding the potential of **employment generation** connected to this sector. The case studies at regional level also show good **working conditions** of the employees, given that more than 85 % of all workers are semi-skilled or skilled. This is also a strength. Unskilled workers often face a far higher insecurity regarding their jobs since they can be given lower salaries and be replaced more easily than semi-skilled or skilled workers are. The only weakness observed is the fact that only around 6 % of the employed workers are female (**gender issue**). This can probably be attributed to the general lack of female workers in the agricultural sector as a whole.

feedstock production • no strengths reported	feedstock production • at case study level only 6 % of the workers are female
feedstock conversion • huge increase of biodiesel export since implementation (800 % between 2006 and 2009) • high percentage of semi-skilled or skilled workers on regional level (85 % to 97 %)	feedstock conversion • no weaknesses reported
feedstock production • huge employment generation expected from the biodiesel production from soy	feedstock production • dependency on regulatory frameworks
feedstock conversion • revenues generated	feedstock conversion • dependency on regulatory frameworks

Fig. 3-4 SWOT matrix for the socio-economic impacts of the production of biodiesel from soybean oil in Argentina (IFEU & IC based on Sbarra & Hilbert 2011)

3.3.4 Linkages: Correlations and trade-offs

The allocation of the observed impacts to the biodiesel production (and in some cases even to soybean production in general) proves difficult. Therefore, only few issues can be used to identify linkages between environmental and socio-economic aspects of soy biodiesel production in Argentina. Regarding the prospect of economic growth there appears to be a trade-off between environmental and socio-economic interests. While having positive impacts on employment generation and generating revenues for the country, the growth of this sector is most likely connected to another broad-scale expansion of the cultivation of soybean. Unless higher yields are obtained, this would potentially result in **land-use competition** which would lead to direct or indirect land-use changes. These in turn cause increased greenhouse gas emissions and are a threat to biodiversity.

3.4 Results of SWOT analysis on case study Brazil

After a short description of the case study the results of the SWOT analysis on the environmental and on the socio-economic aspects associated with sugarcane bioethanol production in Brazil are presented. Finally, the linkages between the environmental and the socio-economic aspects are identified and discussed.

3.4.1 Description of case study

Continent:	South America (North East)
Country:	Brazil (North East)
Climate region:	Tropical moist
Soil type:	High/low activity clay
Feedstock source:	Sugarcane
Product:	Bioethanol
Case study at national level:	The sugarcane value chain in Brazil producing sugarcane on 8.1 million ha of land
Case study at regional level:	The Northeast region since it is a traditional sugarcane production area, with an important participation on the national ethanol and sugar production and socio-economic differences to the largest production region (central South of Brazil); production of sugarcane on about 1.13 million ha of land
Case study at local level:	The São Francisco Mill located north of São Paulo state as the largest organic sugarcane producer in the world cultivating sugarcane on 13,500 ha of land; and the Pindorama Mill as the only cooperative in the sugarcane business in the Northeast region producing sugarcane on 15.000 ha of land

3.4.2 Environmental impacts

The SWOT matrix (Fig. 3-5) shows only a few aspects related to the environmental impacts of sugarcane production in Brazil. The only aspect mentioned as strength is the reduction of greenhouse gas emissions of 73 %, definitely more than the 35 % stipulated by the European Renewable Energy Directive (2009/28/EC). The lack of other strengths or opportunities only means that no particular positive impacts might be found. But that also no negative impacts could be found regarding the aspects not mentioned at all in the SWOT matrix. This should be kept in mind in order to not get a wrong impression. Negative impacts do not have more significance in the sugarcane production in Brazil than positive ones.

• greenhouse gas emission savings of 73 % compared to the fossil reference fuel, see chapter 6.2.2 for details	• negative impacts on the water quality in the vicinity of the organic sugar cane mill (possibly due to the high concentration of sugarcane cropping areas)
• better soil and water management associated with organic farming • reduction of air pollutants due to the no-burning regulation entering in force in 2014	• one of the case study mills on the local level is located only a few kilometres away from an extremely high priority region of biodiversity (risk of land-use change if demand increases)

Fig. 3-5 SWOT matrix for the environmental impacts of the production of bioethanol from sugarcane in Brazil (IFEU & IC based on Machado & Walter 2011)

However, particular aspects identified as weakness are associated with the centralized high-input cultivation which characterizes the long-established sugarcane production in Brazil. An example is the possible harm done to the water quality and the threat for the areas of high conservation value (HCV). Especially the potential threat to areas of high biodiversity is connected to the large-scale plantation system of sugarcane. The negative impact on the water quality adjacent to the organic sugarcane mill is not proven. Organic production is generally associated with no input of chemical pesticides and less input of fertilizer than conventional cultivation.

3.4.3 Socio-economic impacts

Fig. 3-6 shows the SWOT matrix regarding the socio-economic impacts of the sugarcane chain in Brazil. There are several weaknesses and threats related to various socio-economic aspects and connected to the different levels of scale. There is for example a significant difference between the wages paid in the sugarcane sector (national average) compared to the surveyed regional level. Other aspects both covering weaknesses and threats are related to **health issues** and **working conditions**.

On the one hand there are benefits connected to the sugarcane farming regarding health care and insurance. These might reflect the importance of the sugarcane sector for the Brazilian economy and the fact that it has been established for a long time.

On the other hand there are weaknesses such as the still high number of accidents related to sugarcane farming which slightly differ between Brazilian regions. Moreover, only between 5 % and 10 % of the workers in the sugarcane sector are women. Both facts are due to the hard manual labour required for the harvest. These issues might only be improved by increasing the level of mechanization in the sugarcane farming. However, at regional level there is a restriction regarding an increased mechanization: hilly terrain is not suitable for mechanized harvest. Moreover, the implementation of the zero-burning practice will lead to reduced impacts on workers' health.

At the local level, the two mills being surveyed are special in two regards. One of them produces organic sugarcane, the other is cooperatively organised. The latter results in a special way the workers are involved in the company. Therefore, some social benefits / strengths such as life insurance, basic salary or the profit sharing program are closely related to these specific circumstances. These positive examples cannot be considered as typical practice in the sugarcane sector in Brazil.

• at national level wage in sugarcane sector significantly above minimum wage (about 60 % more) • at national level benefits like health insurance, etc. provided by some plants • at case study level social benefits like life insurance, and a basic salary in one mill, Ecosocial seal and a profit sharing program in the other • at regional level less accidents and less share of agricultural work related accidents compared to the national average	• at regional level wages are only around minimum wage and below the regional average wage (only about 80 %) • second highest number of deaths due to labour accidents (of all agricultural sectors) and additional health threats from sugarcane burning • increase of conflicts over land-use (87.5 % between 2003 and 2005) • only between 5 % and 10 % of the workers are women
• at cases study level growth of the sugarcane sector predicted	• at regional level no more potential for sugarcane expansion and no possibility for mechanization due to the high-slopes terrain

Fig. 3-6 SWOT matrix for the socio-economic impacts of the production of bioethanol from sugarcane in Brazil (IFEU & IC based on Machado & Walter 2011)

3.4.4 Linkages: Correlations and trade-offs

The sugarcane sector in Brazil is highly industrialized and associated with an intensive farming system. This results in a trade-off between socio-economic and environmental aspects. The biodiversity on high conservation value areas and the water quality and resources are negatively affected by the applied cultivation system. The economic aspects, though, notably employment generation, clearly benefit from sugarcane cultivation. Moreover, the income of the people involved in the sugarcane bioethanol chain increased and the social and health insurance situation improved.

A negative correlation can be observed regarding the **land-use competition**. This issue results in conflicts over land use and competition with the production of food in socio-economic terms. Regarding the environment, clearing of natural forests and conversion of wetlands are the most important aspects. This potentially increases the emission of greenhouse gases and is a threat to the biodiversity of the affected land.

Another negative correlation is related to the sugarcane burning during the harvest. Negative impacts were observed both in terms of socio-economic as well as environmental aspects. On the one hand, the health of the field workers is negatively affected. On the other hand, in terms of environmental aspects air pollution and the increase of non-CO_2 greenhouse gas emissions are negative impacts. Nevertheless, this will be reduced due to the national regulations.

3.5 Results of SWOT analysis on case study Costa Rica

After a short description of the case study the results of the SWOT analysis on the environmental and on the socio-economic aspects associated with the sugarcane bioethanol production in Costa Rica are presented. Finally, the linkages between the environmental and the socio-economic aspects are identified and discussed.

3.5.1 Description of case study

Continent:	America (Central)
Country:	Costa Rica
Climate region:	Tropical moist
Soil type:	High/low activity clay, volcanic
Feedstock source:	Sugarcane
Product:	Bioethanol
Case study at national level:	Sugarcane ethanol chain in Costa Rica; cultivation of sugarcane on an area of 53,000 ha of land
Case study at regional level:	not conducted; see *Special remarks*
Case study at local level:	CATSA, one of the two Costa Rican companies processing sugarcane into sugar and converting molasses into bioethanol; cultivation of sugarcane on 6,500 ha of land.
Special remarks	Given the small size of Costa Rica (51,100 km^2) and the limited volumes of sugarcane ethanol production (only two distilleries with a total capacity of 54 million L), only the national level and the regional level were assessed in the case study report. Also due its geographical characteristics as well as forest and biodiversity conservation policies, large scale agricultural production is not applied (Cárdenas & Fallot 2011)

3.5.2 Environmental impacts

Fig. 3-7 shows the SWOT matrix regarding the environmental impacts of sugarcane bioethanol production in Costa Rica. Besides the GHG emission savings, biodiversity, air pollution and water quality were identified as being affected by the cultivation of sugarcane and the production of bioethanol. The weaknesses observed in the case study report are related to the limited size of the country as a whole. The advanced process of land used for urbanization, tourism, agriculture and the declaration of protected areas are aspects related to that (Cárdenas & Fallot 2011).

• greenhouse gas emission savings of 69 % compared to the fossil reference fuel, see chapter 6.2.3 for details	• air pollution through sugarcane burning before the harvest • risk of water and soil contamination through excessive application of vinasse in the vicinity of the plant
• no opportunities reported	• iLUC through extension of sugarcane on extensive pastureland

Fig. 3-7 SWOT matrix for the environmental impacts of the production of bioethanol from sugarcane in Costa Rica (IFEU & IC based on Cárdenas & Fallot 2011)

Therefore, any extension of sugarcane in Costa Rica is likely to immediately contribute to land-use competition. This would create the risk of severely negative impacts on the country's high conservation value areas. Also, the aspect of indirect land-use change (so called iLUC) is important. This potentially results in both a loss of biodiversity as well as an increase in greenhouse gas emissions from the soil and from burning the cut biomass. The burning of the biomass associated with the harvest of sugarcane negatively affects the pollution of the air. A potential pollution of water bodies and the soil in the vicinity of the sugarcane conversion plant might take part due to an excessive application of vinasse.

3.5.3 Socio-economic impacts

The SWOT matrix regarding the socio-economic impacts of sugarcane cultivation (see Fig. 3-8) shows several weaknesses and threats. They are connected to both the feedstock production (the actual cultivation) and the feedstock conversion (sugarcane to ethanol). An important aspect in terms of **food issues** is the fact that in Costa Rica the ethanol is produced from the molasses which is a co-product of the production of sugar. Therefore, the conflict between the use of sugarcane for food or fuel is avoided. If the demand and therefore the price for biofuels will rise, an extension of the current sugarcane production is likely to occur. This involves the danger of competing with staple crops for arable land due to the high share of land in Costa Rica under cultivation or other specific uses.

It was reported that 90 % of the company's harvest is mechanized. In terms of **gender issues** a low percentage of women being employed in the sugarcane sector at the local level was observed. This can probably be attributed to the general lack of female workers in the agricultural sector as a whole. The high share of harvest being mechanized is to be assessed mainly positive. On the one hand, it is a clear strength improving **working conditions** and reducing **health** risks and accidents for the workers. On the other hand, it could be seen as a weakness since the number of jobs (irrespective of their quality) is decreased. A high grade of mechanization could contribute to a decreasing number of unskilled and temporary workers. The reported weakness regarding the high share of temporary as well as unskilled workers, though, does not follow this hypothesis. An explanation might be that a part of the land cultivated by the company on the local level is used for cultivating rice. An allocation of the numbers of the workers to either of the crops could not be done. A mechanized harvest is usually not associated with burning the fields before the harvest. In Costa Rica, though, the mechanization of the harvest does not influence the application of the burning. This is rather influenced according to the possible use of the green biomass and to the local regulations regarding the process of burning. As a consequence, 80 % of all sugarcane fields in Costa Rica are still burnt (Cárdenas & Fallot 2011).

feedstock production • at case study level ISCC certified company (social and ecological standards for biomass production) • at case study level about 90 % of the company's harvest is mechanized improving the working conditions and reducing health issues and accident rates	feedstock production • on case study level high share of unskilled workers (about 40 % of all working hours) and high share of temporary workers for the 4 months of harvest season (about 70 %) • only few women work in the sugarcane-to-ethanol supply-chain (e.g. 10 % of all workers at case study level) • at case study level about 90 % of the company's harvest is mechanized reducing the number of workers • biomass burning associated with the harvest is a health problem for field workers
feedstock conversion • at case study level ISCC certified company (social and ecological standards for biomass production) • bioethanol is produced from the molasses avoiding the conflict between food and fuel use	feedstock conversion • only few women work in the sugarcane-to-ethanol supply-chain (e.g. 10 % of all workers at case study level)
feedstock production • no opportunities reported	feedstock production • danger of competition between staple crops and sugarcane regarding extension on extensive pastureland
feedstock conversion • threshold of oil price to generate positive added value of the biofuel sector at given production costs about 90 US-$ per barrel (above this threshold end of 2011)	feedstock conversion • no threats reported

Fig. 3-8 SWOT matrix for the socio-economic impacts of the production of bioethanol from sugarcane in Costa Rica (IFEU & IC based on Cárdenas & Fallot 2011)

3.5.4 Linkages: Correlations and trade-offs

A negative correlation is associated with the potential further expansion of the sugarcane cultivation. This expansion could take place either at the expense of areas of high conservation value (direct land-use change) or at the expense of staple crops (indirect land-use change). The former would threaten biodiversity and cause an increase in greenhouse gas emissions. The latter would increase land-use competition between the cultivation of staple crops and sugarcane. This in turn might result in conflicts and threaten food security.

Another negative correlation is associated with the burning of the biomass during the harvest of sugarcane. This affects both environmental (air pollution and increased GHG emissions) and socio-economic issues (negative impact on the health of affected workers).

The high degree of mechanisation in the sugarcane harvest creates a trade-off between socio-economic and environmental aspects. It negatively affects the environment by creating soil compaction. The impacts on socio-economic aspects are ambiguous. On the one hand, it benefits health issues by reducing the danger of accidents connected to a manual harvest. On the other hand, employment generation is negatively affected. The mechanised harvest requires fewer workforces, thereby decreasing the employment generation.

3.6 Results of SWOT analysis on case study Indonesia

After a short description of the case study the results of the SWOT analysis on the environmental and on the socio-economic aspects associated with the palm oil biodiesel production in Indonesia are presented. Finally, the linkages between the environmental and the socio-economic aspects are identified and discussed.

3.6.1 Description of case study

Continent:	Asia (insular)
Country:	Indonesia
Climate region:	Tropical wet
Soil type:	Low activity clay
Feedstock source:	Oil palm
Product:	Palm oil and biodiesel
Case study at national level:	Palm oil chain in Indonesia producing palm oil on 7.8 million ha of land
Case study at regional level:	North Sumatra as one of the centres of the palm oil industry representing the full extent of the palm oil conversion chain; production of palm oil on about 1 million ha of land
Case study at local level:	Three case studies were selected: a government-owned oil palm plantation (‘nucleus’) with associated smallholder plots (‘plasma’) of 11,000 ha in total and two contrasting examples of independent smallholders (a long-established one producing on about 1,200 ha and a recently-established one producing on about 1,000 ha of land). At the conversion stage, the palm oil mill associated with the state-owned plantation was studied.

3.6.2 Environmental impacts

Fig. 3-9 shows the SWOT matrix about the environmental impacts of palm oil production in Indonesia. While containing several weaknesses, no strengths were mentioned in the case study report.

• no strengths reported	• greenhouse gas emission savings of less than 35 % (5% - 16%) compared to the fossil reference fuel, see chapter 6.2.4 for details • All three case studies lie next to or within regions of high biodiversity and high soil carbon stocks respectively • incidences of water contamination by POME and agrochemicals were reported • decline in soil's organic matter, fertility and soil moisture and increase in soil compaction were reported
• no opportunities reported	• potential of occupation of protected areas and/or regions of high biodiversity and soil carbon stock

Fig. 3-9 SWOT matrix for the environmental impacts of the production of palm oil and biodiesel in Indonesia (IFEU & IC based on Wright 2011)

The weaknesses observed affect all assessed environmental aspects, namely GHG, water resources and quality, biodiversity and soil. Both the feedstock production and the conversion have negative impacts on the environment. The most important weakness is that palm oil biodiesel produced from crude palm oil (CPO) from the mill assessed in this case study does not meet the minimum GHG emission savings stipulated in the European Renewable Energy Directive (>35 % as compared to the fossil fuel reference). This is merely due to the fact that the mill does not capture the methane emitted from the open ponds in which the so-called palm oil mill effluent (POME) is treated anaerobically. All three case studies lie within or next to areas of high biodiversity and high soil carbon stocks. This shows the general problem associated with the implementation of oil palm plantations in Indonesia: the clearing of rain forests or drain of peat land for the implementation of palm oil (Wright 2011). The danger to high conservation value areas, the increase of greenhouse gas emissions as well as the decrease of the quality of the soil through loss of fertility are direct impacts of such a conversion. Soil compaction and application of fertilizer and chemical pesticides are further weaknesses (Wright 2011). The application of the latter is potentially harmful for adjacent ecosystems and their water bodies and also results in increased greenhouse gas emissions.

Another problem is associated with the POME discharge into nearby water bodies. This can result in water contamination of the surrounding area, if not treated and handled appropriately. The palm oil mill needs to be located in the immediate vicinity of the plantation to ensure the quality of the fresh fruit bunches (FFBs) which are pressed to obtain the CPO. Therefore, the negative impacts of the palm oil mill can also affect surrounding rain forests or other areas of high conservation value.

3.6.3 Socio-economic impacts

Fig. 3-10 shows the SWOT matrix regarding the socioeconomic aspects of oil palm plantations in Indonesia. The high number of impacts reflects the great differences especially between the three case studies chosen on the local level (see chapter 3.6.1 for a detailed description). Regarding **economic aspects** the case study report revealed both strengths and weaknesses associated with palm oil production. On one hand, the implementation of palm oil had positive impacts on the employment situation in most villages and improved the general situation of the smallholders. This emphasizes the high economic importance of the production of palm oil. However, the influence of the biodiesel production compared to other uses is difficult to identify. On the other hand, wages in the feedstock production sector for the workers and smallholder farmers, respectively, differed depending on the geographical scale. At the local level the wages were above the minimum wage (up to 200 % in case of some plasma smallholders). The wages paid at national level were on average only around the minimum wage, at the regional level they were even below. Thus, no general statement regarding the economic impact of the palm oil sector in Indonesia as such is possible.

An important aspect identified as weakness is the fact that the **employment generation** on regional level is not expected to continue much. Most of the jobs are created in the initial phase of an oil palm plantation. However, the potential for further expansion was considered small due to the fact that this region was one of the first regions to implement oil palm plantations. Therefore, only few areas remain for further expansion (Wright 2011). A weakness was observed regarding the type of jobs connected to the initiation of new plantations (**working conditions**). Those jobs are only temporary and not associated with the social and health protections of permanent jobs. This is a problem related to the agricultural sector in general occurring in connection with seasonal work. Weaknesses regarding **economic aspects** were identified for smallholders in remote areas not directly associated with a specific plantation. These so-called plasma smallholders heavily depend on single suppliers of seeds and buyers of the fresh fruit bunches. This makes them very vulnerable. This group also faces the problem of accessing the start-up money for the plantations, appropriate knowledge on management techniques and good planting materials. All these aspects result in them having lower yields and lower incomes. The unmanageable debts reported as a major problem in the case study report potentially results from that.

Regarding the conversion of the palm oil to biodiesel, a weakness was observed regarding the price biodiesel producers got paid for their product (**economic aspect**). There is only one domestic company operating as a blender of the biofuel in Indonesia. The company was criticised by biodiesel producers for setting low prices. This, again, reflects a weak bargaining position for single producers if depending on single companies for selling their products.

An explicit weakness was observed regarding the position of women amongst the workers (**gender issue**). First, only 5 % and 15 % of the workers at the plantations and at the conversion mill, respectively, were women. Furthermore, female unskilled workers also received lower wages than their male counterparts did. This is probably due to the hard physical work on the plantations. On the other hand, this might reflect a general aspect of the perception of differences regarding gender in society. Women were for example reported to often work on smallholder plantations. Their work however was not perceived as paid work (Wright 2011).

The **health** care provision and the social security were identified as strengths on all surveyed levels for both the feedstock production and the feedstock conversion. In general it is common for large plantations to have their own health clinics. This aspect is especially important for plantations located far away from other inhabited areas. At the state-owned plantation on the local level, even the associated smallholders cultivating their own plots were provided with health care.

A general problem connected to the palm oil productions in Indonesia is the aspect of **child labour**. This was reported for the regional level in particular. 75 % of the households were reported to let their children work on plantations to raise the low income. This aspect needs to be addressed as a problem not only associated with oil palm plantations but with the overall situation of the people living in this region.

feedstock production • palm oil has improved overall employment situation in most of the case study villages • smallholders claim to be better off with palm oil compared to the past • wages of workers and bigger farmers in smallholder case study at local level above minimum wage (110 % and about 200 % per ha respectively) • at local level the state-owned plantation provides security of employment and social insurance for all their workers • free healthcare for all employees of and all plasma smallholders associated the state-owned plantation at local level • in general large plantations often have their own health clinics • at regional level stable production of rice and slightly increased production of other food in the last ten years	feedstock production • many jobs in initial phase of plantation are temporary and set with day labourers without most of the protections for permanent workers • wages: at national level only around minimum wages; at regional level significantly below minimum wages (only 80 % of minimum wage) • problem with child labour (age 9 to 17) • agrochemical use, harvesting accidents and restriction of rights of association and trade unions at the regional level • weak bargain position and low income of smallholders due to little organisation and their dependency on middlemen or farm gate prices • competition between food use of palm oil and use as biofuel • transition from net producers to net consumers of food makes people more vulnerable to high food prices • smallholders of one case study region converted rice paddies into more profitable oil palm plantations causing a deficit in regional food production • increasing number of conflicts across Indonesia over land rights and unfulfilled promises • in the case study regions only 5 % of the workers at the plantation and 15 % at the mill are women • female unskilled workers receive lower wages than male ones • at national level problems for smallholders in remote areas to gain access to money (unmanageable debts), good planting material and knowledge about management
feedstock conversion • at the mill associated with the state-owned plantation unskilled workers' wage is much higher than minimum wage (nearly 340 %) • all permanent workers at the mill at local level are provided with housing, healthcare, children's education and other bonuses • free healthcare for all employees of the mill on local level	feedstock conversion • only one (state owned) company for biofuel blending paying low prices to the producers for their biodiesel
feedstock production • well paid feedstock for oil production	feedstock production • low potential for future employment generation on regional level
feedstock conversion • increasing market	feedstock conversion • slower growth of the biofuel sector at national level than predicted results in less job creation

Fig. 3-10 SWOT matrix for the socio-economic impacts of the production of palm oil and biodiesel in Indonesia (IFEU & IC based on Wright 2011)

Also, the application of agrochemicals and harvesting accidents contribute to negative impacts on the working conditions at the regional level. In connection with restrictions regarding the rights of the workers, this needs to be addressed as an important weakness. In the case study report it was mainly reported for the regional level.

The last important issue reported for the socio-economic aspects of the case studies refers to the **land-use competition** between food and palm oil production. Most of the reported aspects have to be assessed as clear weaknesses. Only at the regional level a strength was identified. In North Sumatra, a stable or even slightly increased production of food crops was observed in the last ten years. This is especially remarkable considering the fact that for this region a low potential for expansion of palm oil production was identified. Generally, this would be expected to result in an even heavier conflict of palm oil and food production for land. For all the other case studies, the competition of palm oil cultivation and food production was addressed as a problem. This issue consists of several aspects closely related to each other. First, the conversion of land to oil palm plantations previously used for food production might be due to land grabbing and without or only with a limited agreement on the side of the owner of the land. This aspect is reflected in the reported increasing number of conflicts across Indonesia over land rights and unfulfilled conditions. The second possible reason for a conversion of land might be the economic incentive of the more profitable cultivation of palm oil trees. This aspect was reported for smallholders on the local level converting rice paddies into oil palm plantations. However, this is likely to create deficits regarding the production of food for the affected area. The economic problem of newly implemented oil palm plantations is the delayed financial output after 3-5 years. The combination of both aspects results in a transition of the affected people and the whole region from net producers to net consumers of food. This makes them more vulnerable to rising food prices. A third aspect regarding the competition of food and fuel lies within the sector of oil palm plantation. Oil palm has emerged as a feedstock for biodiesel production only in the last few years. Before, it was used for food (vegetable oil) and cosmetics only. Diverting the use of palm oil to biodiesel, therefore, also creates a competition between food and fuel.

3.6.4 Linkages: Correlations and trade-offs

Linkages between the environmental and the socio-economic aspects of palm oil production in Indonesia refer to both trade-offs and negative correlations. A negative correlation is observed regarding the POME discharge into adjacent water bodies without capturing the emitted methane. This negatively affects the environment regarding the increase of greenhouse gas emissions and the danger of pollution of affected water bodies. The last aspect is harmful to the environment and the people in the surrounding villages at the same time. The pollution of drinking water is a threat to the health of the people. Another negative correlation is the application of agrochemicals. It also negatively affects the health of workers and people from the surrounding villages. In terms of the environment, it means a threat to the biodiversity of the surrounding areas. The third negative correlation refers to the aspect of land-use competition. Oil palm plantations compete for land with natural forests. This negatively affects the biodiversity of the affected high conservation value areas. Also, it might increase the emissions of greenhouse gases in case of conversion of peat soils. On the other hand, it results in conflicts over land use and competition with the production of food in socio-economic terms.

The trade-off is associated with the overall implementation and maintenance of oil palm plantations. In terms of economic aspects, positive impacts are observed regarding the general economic situation (employment generation, income and social insurance) of most of the affected farmers and villagers. In terms of environmental aspects, though, the impacts are negative regarding several issues (see above).

3.7 Results of SWOT analysis on case study Tanzania

After a short description of the case study the results of the SWOT analysis on the environmental and on the socio-economic aspects associated with the Jatropha oil and biodiesel production in Tanzania are presented. Finally, the linkages between the environmental and the socio-economic aspects are identified and discussed.

3.7.1 Description of case study

Continent:	Africa (East)
Country:	Tanzania
Climate region:	Tropical moist/montane
Soil type:	High/low activity clay, volcanic
Feedstock source:	Jatropha
Product:	Jatropha oil and biodiesel
Case study at national level:	Sun Biofuels company[1], as an example for a foreign subsidiary company investing in large scale plantations of Jatropha in Tanzania (2,000 ha)
Case study at regional level:	Arusha region representing an area where Jatropha hedges have been growing for many years. Diligent Company is involved in Jatropha seed collection from out-growers (smallholder farmers) who cultivate Jatropha on an area of about 3,000 ha of land and processing at the central plant in Arusha municipality.
Case study at local level:	Leguruki village representing smallholder farmers groups in an area suitable for Jatropha production and equipped with an Energy Service Platform (ESP); total area of the village about 2,200 ha with about 1,700 ha of arable land. Jatropha processing and local utilisation is enabled through production of bio-products (such as soap, insect repellent, oil, etc).

3.7.2 Environmental impacts

The SWOT matrix regarding the environmental aspects (see Fig. 3-11) shows strengths of the Jatropha production in Tanzania regarding most of the considered aspects. Greenhouse gas emissions, water resources and water quality and soil are affected.

[1] At the moment of writing this report Sun Biofuels have gone into bankruptcy and the company has been bought by another investor.

• greenhouse gas emission savings of 50% - 58 % compared to the fossil reference fuel if cultivated by smallholders on marginal land, see chapter 6.2.5 for details • cultivation of Jatropha without irrigation (rain-fed conditions) • positive impacts of Jatropha cultivation on land degradation and deforestation	• greenhouse gas emission savings of less than 35 % compared to the fossil reference fuel if cultivated on plantations on good land, see chapter 6.2.5 for details • the majority of the main investors work or plan to work in areas of high conservation value (HCV)
• potential of Jatropha to contribute to mitigation of soil erosion	• large scale production means large monocultures and may need irrigation • yield might not be as high as expected • possibilities of expansion into forested areas

Fig. 3-11 SWOT matrix for the environmental impacts of Jatropha oil and biodiesel production in Tanzania (IFEU & IC based on Sawe et al. 2011)

A weakness and threat can be observed regarding areas of high conservation value (HCV). The positive and negative impacts belong to different cultivation systems of Jatropha.

The positive impacts of Jatropha cultivation on land degradation and deforestation are only given if an extensive farming is conducted under rain fed conditions. This cultivation implies that Jatropha is cultivated in hedges around homestead gardens and graves as protection, by means of a combined cultivation with other crops (so-called intercropping) or on degraded land. All these systems do not need extra irrigation. This decentralized way of cultivation is long established among farmers and villagers in Tanzania. Therefore, it is mainly without negative impacts and even the potential to benefit the environment (Sawe et al. 2011). However, the yield of Jatropha cultivated in an extensive system is rather low.

The negative impact is associated with Jatropha being cultivated in an intensive farming system. This system is connected to large scale plantations of Jatropha. The intensive farming of Jatropha is likely to be harmful to the environment by not considering areas rich in terms of biodiversity (e.g. areas of high conservation value, HCV). It is connected to a central management of Jatropha cultivation by major investors. This is in contrast to the smallholder farmers and villagers associated with the extensive farming system.

In case of rising prices for straight Jatropha oil (SJO) or Jatropha biodiesel more land could be devoted to Jatropha cultivation. This might result in an increased land-use competition.

3.7.3 Socio-economic impacts

The SWOT matrix about the socio-economic impacts of Jatropha production in Tanzania (see Fig. 3-12) shows a great number of both strengths and weaknesses. As seen in the environmental part, a distinction can be made between the impacts of Jatropha cultivation regarding the two farming systems. The decentralized extensive farming system mainly by smallholder farmers and villagers has positive impacts on land-use competition and conflicts as well as the competition of Jatropha with food. The centralized intensive cultivation of Jatropha is associated with negative socio-economic impacts. On the national level, Jatropha is reported to be cultivated on prime arable land, therefore competing with the cultivation of food. Also, illegal land acquisitions were reported due to which villagers lost their land. The issues connected to these conflicts can be regarded as the main problem of biofuels.

feedstock production • at regional level all wages paid are above the minimum wage (13 % to 50 % higher) • great employment generation on regional level reported and sustainable employment generation is expected on national level at every stage of production, processing and marketing • at local level the surveyed group was able to set its own regulations and working-framework • at regional level no competition regarding high-quality cultivation land due to intercropping cultivation of Jatropha • land-use competition was avoided at regional and local level by smallholders providing companies with feedstock without losing their right of land • Jatropha chain generates income for women growing and selling seeds • during Jatropha feedstock production, women are treated equally and paid equally	feedstock production • some companies do not provide workers with full protective equipment e.g. for agro-chemicals application • no workers union implemented in any of the surveyed companies • significant number of workers are employed as casual workers without social security, health benefits nor health insurance • at regional and local level smallholders providing companies with feedstock do not have access to company's health care facilities • at national level Jatropha is reported to be cultivated on prime land, thus, competing with food crops • problem of workers not being able to cultivate their own land due to long absence from home • at national level illegal land acquisitions were reported resulting in villagers losing their land
feedstock conversion • Jatropha chain generates income for women producing soap • press machines at the local level in some areas enable small groups of villagers to independently process Jatropha seeds	feedstock conversion • danger of contamination of food oils with (inedible) Jatropha oil • significant number of workers are employed as casual workers without social security, health benefits nor health insurance and so on • villagers without local press machine rely on middlemen to sell their seeds which results in them getting paid lower prices
feedstock production • huge potential of employment generation on regional level due to the missing mechanization potential	feedstock production • need to improve policies, acts, laws and regulations in order to ensure that local people benefit from biofuel potential and resources existing in their areas
feedstock conversion • Bio-products from Jatropha feedstock processing are used for biogas production and as fertilisers.	feedstock conversion • rising prices of SJO or JME may result in farmers allocating more land of current food production to Jatropha

Fig. 3-12 SWOT matrix for the socio-economic impacts of Jatropha oil and biodiesel production in Tanzania (IFEU & IC based on Sawe et al. 2011)

From an **economic perspective**, Jatropha can be assessed as having an overall positive impact. Huge potentials for **employment generation** on both national and regional level are associated mainly with the feedstock cultivation. The average wages in this sector are also above the minimum wage in Tanzania. This is probably connected to the biodiesel sector generating a great value along its production chain at least a part of which trickles down to the initial feedstock cultivation phase.

Regarding **gender issues** these economic benefits have positive impacts on the position of women. Both the Jatropha cultivation and the conversion generate income for women. This might enable them to become more independent and improve their position in the society. Thus, the Jatropha production chain is likely to influence on the Tanzanian societal structure.

Another important aspect in this context is the access to press machines for farmers being involved in the Jatropha cultivation. This has the potential to generate more income for the smallholder farmers by enabling them to produce oil, a product further processed and therefore more valuable. Also, this would break off their dependency on middlemen when selling their seeds.

Regarding **health issues** of the worker in both the feedstock production and the conversion sector, only negative impacts have been observed: Some companies do not provide full protective equipment for hazardous work such as chemical application. A great number of workers are not provided with social or health security. On regional and local level the smallholders providing the companies with feedstock have no access to the company's health care facilities.

3.7.4 Linkages: Correlations and trade-offs

The most important linkage regarding environmental and socio-economic aspects of Jatropha biodiesel production in Tanzania refers to the different systems of Jatropha farming.

The cultivation of Jatropha in the extensive system on the one hand shows a positive correlation. It results in overall positive impacts in terms of socio-economic aspects without having any negative impacts in environmental terms. On the contrary, cultivating Jatropha this way even has the potential to enhance the soil quality and reduce the greenhouse gas emissions compared to the fossil reference system.

On the other hand the cultivation of Jatropha in the intensive system shows a negative correlation of socio-economic and environmental aspects. Aiming at the highest yield possible it is often associated with the disregard of environmental problems. Moreover, it potentially increases land-use competition and conflicts and is a danger in terms of food issues. Also, societal structures are disrupted and villagers and farmers are put at a disadvantage. Assessing Jatropha cultivation, therefore, is clearly connected to the applied farming system. If Jatropha biodiesel production is implemented on a broad economic scale higher yields will probably be necessary. Therefore, the intensive cultivation system is most likely to be implemented. This would result in most of the positive aspects of (extensive) Jatropha cultivation being lost and the negative ones to prevail.

The huge potential of employment generation in rural areas through plantations and smallholder Jatropha cultivation shows a positive correlation. It clearly improves the economic situation of the affected households. In return, the villagers do not anymore rely on natural forests and other woodlands for income generation such as charcoal production, timber and other forest products. This would ease the pressure on these natural areas, protecting high conservation value areas.

A negative correlation exists regarding the application of agrochemicals. The lack of protective equipment for workers applying them is a danger for their health. The application itself negatively affects the environment in terms of biodiversity, water quality and soil.

The initiation of a new industrial sector in a country and its society is often accompanied with a lack of an appropriate regulatory and legal framework. However, such a framework is necessary to be implemented in the beginning. Only then can the above mentioned conflicts such as illegal land acquisition and the problem of land-use competition and conflicts be prevented. This would also prevent major changes associated with potential negative impacts on both the environment and the socio-economic structures. This is another important aspect regarding the production of biodiesel from Jatropha in Tanzania.

3.8 Results of SWOT analysis on case study Mali

After a short description of the case study the results of the SWOT analysis on the environmental and on the socio-economic aspects associated with the Jatropha oil and biodiesel production in Mali are presented. Finally, the linkages between the environmental and the socio-economic aspects are identified and discussed.

3.8.1 Description of case study

Continent:	Africa (North-West)
Country:	Mali
Climate region:	Tropical moist/dry
Soil type:	High/low activity clay
Feedstock source:	Jatropha
Product:	Jatropha oil and biodiesel
Case study at national level:	The Jatropha value chain in Mali producing on an estimated 7,300 ha of land
Case study at regional level:	The Region of Koulikoro with different Jatropha initiatives by the public sector, civil society and the private sector producing Jatropha on estimated 2,000 ha of land
Case study at local level:	The company Mali Biocarburant SA – the only company producing biodiesel for the local market and a major innovator in the Jatropha value chain – and the rural electrification project of the town of Garalo (Garalo Bagani Yeleen) – aimed at providing electricity to 10,000 inhabitants in the rural municipality of Garalo through locally grown and processed Jatropha oil; production of Jatropha is conducted on about 400 ha of land
Special remarks	In Mali, the Jatropha sector is still in its initial phase (Burrell et al. 2011). Therefore, only very little information was available about the impacts of Jatropha cultivation and processing regarding economic and environmental aspects.

3.8.2 Environmental impacts

Besides the fact that a reduction of greenhouse gas emissions could be achieved, no more information specifically aimed at environmental impacts of the Jatropha chain in Mali was available (see Fig. 3-13 for the SWOT matrix). This can be attributed to the fact that so far in Mali Jatropha is only produced in a decentralized extensive farming system (Burrell et al. 2011). Here, Jatropha is cultivated in hedges or in an intercropping farming system.

Thereby, it potentially positively influences land degradation as well as the soil fertility. The possible future broad-scale initiation of the Jatropha biodiesel production – like all centralized intensive farming system – faces the risk of significant environmental impacts (see section 3.7).

• greenhouse gas emission savings of 50% - 74 % compared to the fossil reference fuel, see chapter 6.2.6 for details	• no weaknesses reported
• potential of Jatropha to contribute to mitigation of soil erosion / land degradation, i.e. to the conservation of soil fertility	• large scale Jatropha cultivation might threaten environmental assets such as biodiversity (e.g. in case of land-use changes) or water (e.g. in case of irrigation or inappropriate use of agrochemicals)

Fig. 3-13 SWOT matrix for the environmental impacts of Jatropha oil and biodiesel production in Mali (IFEU & IC based on Burrell et al. 2011)

3.8.3 Socio-economic impacts

The SWOT matrix regarding the socio-economic impacts of Jatropha production in Mali (Fig. 3-14) is difficult to interpret: it does show quite a few strengths, but one has to take into account that the Jatropha sector is hardly developed at national level. So far, the initiation of the sector did not result in large-scale changes regarding the established agricultural system: Jatropha is mainly cultivated as an additional crop by intercropping farming or as hedges. As yet, no conflicts regarding **land-use competition** were reported since in Mali Jatropha is only grown on marginal or even degraded land.

• income from cultivation of Jatropha for smallholder reaching up to double the income from rice cultivation • no competition regarding cultivation land due to intercropping cultivation technique of Jatropha • important involvement of women regarding collection of seeds and transformation of by-products for soap production	• limited amount of production for a national level market
• great creation of employment expected in association with the evolution of the Jatropha market • potential of Jatropha chain to empower women significantly	• no threats reported

Fig. 3-14 SWOT matrix for the socio-economic impacts of Jatropha oil and biodiesel production in Mali (IFEU & IC based on Burrell et al. 2011)

The cultivation of Jatropha generates an extra income without requiring a corresponding amount of extra work. Thus, the **micro-economic impacts** can clearly be regarded as strength. Another strength is connected to the Jatropha chain empowering women by involving them in different parts of the Jatropha value chain (**gender issue**).

Even though few weaknesses or threats were reported, the aspects mentioned in connection with the Jatropha chain in Tanzania are also valid. Here, the initiation of centralized intensive cultivation is to be addressed as the major issue.

3.8.4 Linkages: Correlations and trade-offs

The way Jatropha has been and currently is cultivated in Mali has strong positive impacts in terms of both socio-economic and potentially environmental aspects. On the one hand, it generates additional income for farmers as well as own income for women. This positively influences the economics and employment generation as well as gender issues. On the other hand, it potentially benefits the environment by decreasing land degradation and increasing the fertility of soils. This connection between a small-scale farming system and overall positive impacts has already been observed for the Jatropha chain in Tanzania (see section 3.7). Therefore, the danger regarding a change of the cultivation system introducing a rather intensive farming system is also the same. Only in Mali, it has not been observed yet, so that possible precautions like adjusting the legal and regulatory framework would be even more efficient to avoid negative impacts.

3.9 Results of SWOT analysis on case study Canada

After a short description of the case study the results of the SWOT analysis on the environmental and on the socio-economic aspects associated with the production of 2nd generation biofuels in Canada are presented.

3.9.1 Description of case study

Continent:	America (North)
Country:	Canada
Climate region:	Cool temperate moist/dry, boreal moist/dry
Soil type:	High/low activity clay
Feedstock source:	Lignocellulosic biomass
Product:	Second generation conversion technologies
Case study at national level:	The lignocellulosic biomass supply chain in Canada
Case study at regional level:	British Columbia was chosen as the regional case study given that it is one of the most important forestry provinces within the country and also because one of the local case studies is located in the province.
Case study at local level:	Two processes were selected: the lignin and ethanol production process of Lignol, and the pyrolysis oil production process of BTG. Both BTG and Lignol have no large demo plants in Canada yet. Tembec's forestry operations in the Kootenay area in British Columbia was selected as a case for biomass supply. Tembec is one of the largest forest products companies in Canada and has one of the largest estates of certified forestry operations.
Special remarks	The lignocellulosic biomass used for second generation biofuel production in Canada is a waste product from the paper and pulp mill sector. Since no feedstock supply chain as such exists the forestry sector was analysed to gather information about the impacts of feedstock production.

3.9.2 Environmental impacts

Within this case study, environmental impacts were not looked at since it was not foreseen in the Description of Work.

3.9.3 Socio-economic impacts

The SWOT matrix regarding the socio-economic impacts of second generation conversion technologies in Canada shows several issues referring to both strengths and weaknesses (see Fig. 3-15).

feedstock production • forestry sector on regional level accounts for 15 % of all economic activity • forestry sector as major employer in rural areas • forestry sector's wages on regional level tend to be higher than those of other industries (on average about 12 % higher) • on case study level local workers are hired if available • employment standards are installed nationwide to ensure labour laws and good working conditions (including health and safety, working hours, right to collective bargaining, etc.) • on regional level the number of fatalities and accidents has declined during the last years • on case study level very few accidents were counted in the last years • no competition with food production for food but additional gain during food items provided by the woods (mushrooms, honey, game) • the company on case study level is FSC certified, therefore ensuring the protection of social, cultural and ecological high conservation value (HCV) areas	feedstock production • hard and dangerous work of the forestry sector result in accidents and health problems • on national level wage gap of about 13 % between women and men in the same profession • forestry sector traditionally male dominated (only 15 % female workers on case study level)
feedstock conversion • labour laws are installed on the national and provincial level to provide for standard working conditions	feedstock conversion • on national level wage gap of about 13 % between women and men in the same profession
feedstock production • no land use competition due to stable forest estate, sustainable forestry and clearly defined land use planning	feedstock production • stagnation in the forestry sector regarding employment generation in the last years on case study level
feedstock conversion • good economic prospect and employment generation potential for conversion facilities on national and regional scale assuming a conversion plant on every paper and pulp mill	feedstock conversion • conversion plant is associated with several health issues, i.e. noise and gas emissions which need appropriate countermeasures

Fig. 3-15 SWOT matrix for the socio-economic impacts of lignocellulosic biomass production and second generation conversion technologies in Canada (IFEU & IC based on van Sleen et al. 2011)

The **economics** can generally be regarded as positive. The forestry sector is important for economic activity and as employer in rural areas. Only on case study level, the **employment generation** has stagnated during the last few years. Another strength is connected to the fact that the wages in the forestry sector tend to be higher than in other sectors. This is due to the dangerous and hazardous work in this sector. Therefore, **working conditions** and

health issues must be assessed ambiguously. The hard manual works resulting in health problems and accidents were identified as weaknesses. Nevertheless, the extensive labour laws installed all over the country guaranteeing good working conditions and health and safety being a major aspect are clearly strengths.

Regarding health issues, on regional and case study level the number of fatalities and accidents have declined in the forestry sector. This can be regarded as strength. A possible future health issue is associated with conversion plants. Several health problems are connected to their installation requiring appropriate actions to avoid negative impacts on adjacent inhabitants. Similar to the feedstock production, the adverse health issues of the conversion facilities are combined with good economic prospects and potential for employment generation.

Regarding **food issues**, no competition between lignocellulosic biomass and food production was reported neither expected. On the contrary, the forest was assessed as providing additional food items. This was clearly identified as strength. In addition to that, the company on case study level is Forest Stewardship Council (FSC) certified, therefore required to especially ensure the protection of social, cultural and ecological high conservation value (HCV) areas. Also, no **land-use competition** was reported neither expected. The forest estate has been stable for the last years and sustainable management and clearly defined land use planning also contribute to that. Regarding **gender issues**, a wage gap was reported for the national level. According to that, women earn 13 % less than men in the same profession. This clearly is a weakness. Another weakness is rather associated to a general aspect of the forestry sector. Due to the hard work, only 15 % women are employed in this sector.

3.9.4 Linkages: Correlations and trade-offs

Linkages could not be identified since the environmental impacts were not assessed in the case study (cf. chapter 3.9.2).

3.10 Summary and discussion

Summary of results

Through the SWOT analyses on the Global-Bio-Pact case studies, **all types of linkages** between socio-economic and environmental impacts **could be identified** (see classification in chapter 3.2). In the following, a number of examples are given (non-exhaustive list):

- **Positive correlation** between socio-economic and environmental impacts ('win-win situation'):
  - The extensive cultivation of Jatropha is not disturbing (rather improving) the socio-economic situation of the affected people and does not negatively affect the environment. Potentially, it even improves the environmental properties of the cultivated land. Therefore, a positive correlation was identified between socio-economic aspects (e.g. economics, employment generation and gender issues) and environmental aspects (e.g. soil improvement).
- **Trade-off** between socio-economic and environmental impacts:
  - Regarding the intensive cultivation of Jatropha, negative environmental impacts were reported related to clearing of natural forest and the use of heavy machinery and pesticides. This negatively influences areas of high biodiversity, water quality as well as greenhouse gas emissions. Also soil erosion and the loss of soil fertility are affected. However, since in terms of socio-economic aspects, positive impacts on the economic situation of farmers and villagers were reported, an overall trade-off was identified.
- **Negative correlation** between socio-economic and environmental impacts ('lose-lose situation'):
  - A negative correlation was identified for sugarcane bioethanol in case the harvest involves burning of the field which is associated with negative impacts on workers' health. It also increases air pollution and greenhouse gas emissions in terms of environmental aspects.
  - A negative correlation was identified for palm oil biodiesel, in case the palm oil mill effluent (POME) is not properly treated: POME increases greenhouse gas emissions and decreases water quality of adjacent water bodies. At the same time, it negatively affects human health through the pollution of drinking water of surrounding villages.
  - In case of inappropriate application of agrochemicals, a negative correlation was identified. In terms of environmental aspects, it is harmful to the biodiversity of adjacent areas and decreases water quality. Also, it has negative socio-economic impacts on workers' health and drinking water quality.
  - Land-use conflicts and land-use changes often lead to a negative correlation. From an environmental point of view, land-use changes threaten biodiversity and (in most cases) increase greenhouse gas emissions. In terms of socio-economic impacts, LUC often has an impact on food security issues: diverting land away from food and feed production makes the affected people more vulnerable to rising food prices.

Land-use conflicts were mostly reported in relation to an intensive, large-scale cultivation of a certain feedstock, in some cases connected to foreign investments. To prevent such land-use competition, a strict implementation of a country's laws and regulations is absolutely necessary. In those countries already facing the respective negative impacts the application needs to be controlled thoroughly. For countries like Mali and Tanzania facing the broad-scale introduction of Jatropha for biodiesel production the situation is different. To prevent such negative impacts it is absolutely necessary to implement such a framework beforehand. Thereby, these impacts might be able to be minimized.

Limitations and remarks

All information regarding environmental and socio-economic impacts used for the SWOT analyses was entirely obtained from the Global-Bio-Pact case study reports. The information was condensed and interpreted by IFEU and Imperial College which bears the risk that some aspects have been omitted. For in-depth insights and a more comprehensive picture on the situation in each of the countries, the reader is referred to the original case study reports.

Two major **limitations** were identified:

- Completeness
- Reference point in time / baseline situation

Regarding completeness, it has to be kept in mind that the case study partners were asked to gather information related to certain pre-defined environmental and socio-economic aspects (see chapter 3.2). As a consequence, other potentially important aspects were not addressed. Moreover, in some cases, it was not even possible to obtain the requested information related to some of the pre-defined aspects, so the picture given might be incomplete and even biased.

IFEU and Imperial College only had very limited possibilities to cross-check and validate the information provided by the partners. For example, neither direct land-use changes (dLUC) nor indirect land-use changes (iLUC) were reported in any of the case studies. Consequently, the greenhouse gas balances were calculated without dLUC and iLUC emissions. If the LUC emissions were taken into account, the results would be significantly influenced.

The second limitation is related to the fact that no reference point in time and reference land use (baseline situation) was defined. Data from different points in time were rarely provided in the case study reports. Such information, however, is absolutely necessary for two reasons: 1) to identify developments or trends between two different points in time, i.e. the socio-economic and environmental situation before and after the implementation of the respective feedstock cultivation, and 2) to establish causality links between observed impacts and the underlying drivers.

Since most of the biomass feedstocks (except Jatropha) used for biofuels have been cultivated long since for other (mainly food) purposes, the difference between a business-as-usual scenario and a non-food biomass scenario should be measured. Regarding feedstock cultivation, the assessment of environmental impacts heavily depends on the reference land use (baseline situation): if compared to unused land, annual crops usually perform significantly worse. However, if annual crops (for biofuel production) are compared to other annual crops (for food or feed production), differences are mostly less distinct. Due to the absence of a clear reference land use, it was not possible to link the reported impacts for the various types of feedstock to the implementation of biofuel production. Most impacts analyzed are rather connected to the general production of the respective agricultural commodity.

The fact that extensively cultivated Jatropha seems to perform better than the other crops can be regarded as an artefact. First, Jatropha has just recently been introduced as a potential feedstock for the production of biofuels. Until then, the non-food plant was only cultivated as means of protection hedges yielding goods for small-scale trade. All other types of feedstock have been cultivated long since and were mainly used for food purposes or for high-value goods, making large-scale farming feasible. Therefore, the two groups of feedstock differ regarding three aspects: time and scale of implementation and their previous use.

Thus, the assessment of the impacts could only be conducted in terms of a description of the respective status quo and a knowledge-based outlook on possible impacts. This made the application of SWOT analysis to the conducted case studies quite difficult.

In addition to these limitations, the authors would like to make the following **remark**:

Regarding the environmental impacts of biofuels and bioproducts, the results are often ambiguous showing systematic trade-offs, i.e. a distinct pattern of advantages and disadvantages (Rettenmaier et al. 2011). Usually, the use of biofuels and bioproducts (instead of petroleum-based fuels and products) saves of non-renewable energy resources and helps mitigating climate change[2]. At the same time, other environmental impacts are more pronounced, e.g. impacts on biodiversity, water and soil. From a scientific point of view, an objective conclusion regarding the overall environmental performance cannot be drawn[3]. In other words: there are even **trade-offs between different environmental impacts**, not only between socio-economic and environmental impacts.

[2] Provided that no direct land-use changes (dLUC) and indirect land-use changes (iLUC) occur.

[3] An overall evaluation has to be based on (subjective) value-choices, e.g. by ranking the impact categories in a certain hierarchy (e.g. high, medium, and low priority). For obvious reasons, different individuals, organisations and societies have different preferences; therefore different rankings may be the outcome of the same (objectively obtained) scientific results.

4 Interpretation and conclusions

The aim of this report was to reveal linkages between socio-economic and environmental impacts of biomass production in developing countries. Through the SWOT analyses on the Global-Bio-Pact case studies, **all types of linkages** between socio-economic and environmental impacts **could be identified**: positive correlations, trade-offs as well as negative correlations.

Interpretation

The interpretation of the identified linkages between socio-economic and environmental impacts is quite complex. First of all, this is because environmental impacts are a complex issue in themselves. They differ in terms of time scale (persistence), spatial scale (ubiquity), and (ir-)reversibility, among others.

Environmental impacts often develop insidiously over a long period of time, i.e. significant **time lags** might occur between the dose (release of a harmful substance) and the associated response (damage to organisms or ecosystems). Since ecosystems are functioning on a long time scale, environmental impacts tend to be overlooked by the short-sightedness of politics and society. Often, short-term economic profits are preferred over long-term environmental benefits. This is one of the main reasons for trade-offs between socio-economic and environmental impacts.

Moreover, the relationship between dose and response is often **non-linear** showing for example an abrupt change if a certain threshold is passed. In case this change is irreversible, the threshold is also called a tipping point. Last but not least, the **response depends on** the nature of the affected **organisms or ecosystems**, more specifically their resistance (ability to withstand) and resilience / elasticity (ability to tolerate). Thus, the same dose causes different responses in different environments.

Combining these insights and the concept of ecosystem services (chapter 2), this means that environmental impacts lead to **changes in ecosystem services**[4] which in turn **negatively affect the constituents of human well-being**. Despite to the complex relationship between dose and response (see above), one could postulate that there is a gradient from positive correlations to trade-offs to negative correlations, along which ecosystem services are increasingly deteriorated:

- **Positive correlations** (limited environmental impacts of a certain activity, no changes in ecosystem services, positive socio-economic impacts): The SWOT analysis of Global-Bio-Pact case studies suggests that extensive feedstock cultivation and conversion systems seem to result in positive correlations.
- **Trade-offs** (considerable negative environmental impacts, visible deterioration of ecosystem services, but still at least short-term positive socio-economic impacts): More intensive feedstock cultivation and conversion systems seem to entail trade-offs. This is the

[4] Ecosystem services include provisioning, regulating, and cultural services that directly affect people and supporting services needed to maintain the other services (see chapter 2).

case for many Global-Bio-Pact systems. However, one has to keep in mind that there is a continuum rather than a sharp borderline between extensive and intensive cultivation.

- **Negative correlations** (severe negative environmental impacts, loss of ecosystem services, negative socio-economic impacts): Regarding the Global-Bio-Pact case studies, negative correlations between socio-economic and environmental impacts can mostly be explained by land-use conflicts and land-use changes as well as by inappropriate management practices – the latter both in terms of feedstock production (e.g. inappropriate application of agrochemicals) and conversion (e.g. inappropriate treatment of effluents).

This holds especially for ‘provisioning’ and ‘regulating’ ecosystem services which affect some but not all constituents of well-being. ‘Security’, ‘basic material for good life’ and ‘health’ are affected, whereas there is only a weak linkage between the ecosystem services mentioned above and ‘good social relations’ and ‘freedom of choice and action’.

Conclusions

The authors would like to emphasise that **the identified linkages (correlations and trade-offs) are case study-specific**. Due to the limited number of case studies (one or two per feedstock), a trend or even a general rule (in the sense of a direct causal linkage) for a certain feedstock or for a certain biofuel or bioproduct cannot be deduced.

From our analyses we conclude that

- trade-offs and negative correlations between environmental and socio-economic impacts are a sign of deteriorations of environmental services which negatively affect the constituents of human well-being ‘security’, ‘basic material for good life’ and ‘health’. They are often related to **inappropriate management practices** during feedstock production and conversion which either **reflect the absence of respective regulations or** at least a **weak law enforcement by the country’s institutions**. Certification could help here, at least by raising awareness.
- the second cause for trade-offs and negative correlations is **land use conflicts and land-use change**. For direct land-use change (dLUC), the same applies as for inappropriate management practices (see above). However, certification doesn’t help resolving the issue of indirect land-use change (iLUC).
- the impacts associated with the production of a feedstock are fairly independent of its use, i.e. whether the feedstock is used for biofuels / bioproducts or for other purposes. Therefore, most of the conclusions drawn are applicable for the general cultivation of the respective feedstock. They do not necessarily reflect the specific impact of the biofuel production as such. Therefore **it is important to apply the same rules for all agricultural products irrespective of their use for food, feed, fibre or fuel**.
- most of the linkages between environmental and socio-economic impacts can be detected at local level whereas **some linkages can only be detected at country level** (or even higher), e.g. impacts on food security. Furthermore, some of the linkages regarding food security will need additional studies and a different methodology to be able to fully demonstrate that biofuel production may cause food insecurity and in how far biofuel mandates in developed countries and / or globally rising energy prices contribute to that.

5 References

BIOGRACE (2011): Excel based biofuel GHG calculations, version 4b – Public. Developed by the BioGrace consortium within the framework of the IEE-funded project "Harmonised Calculations of Biofuel Greenhouse Gas Emissions in Europe" Download: http://www.biograce.net/content/ghgcalculationtools/excelghgcalculations

BURRELL T., OUATTARA O., SOKONA M., TOGOLA I. (2011): Socio-Economic Impacts of the Jatropha chain in Mali. Case study report (D 2.4) within the Global-Bio-Pact project 'Global Assessment of Biomass and Bioproduct Impacts on Socio-economics and Sustainability'.

CÁRDENAS A., FALLOT A. (2011): Socio-Economic Impacts of the sugarcane-to-ethanol production chain in Costa Rica. Case study report (D 2.5) within the Global-Bio-Pact project 'Global Assessment of Biomass and Bioproduct Impacts on Socio-economics and Sustainability'.

DE HAES H.A.U., JOLLIET O., FINNVEDEN G., HAUSCHILD M., KREWITT W., MÜLLER-WENK R. (1999a) Best Available Practice Regarding Impact Categories and Category Indicators in Life Cycle Impact Assessment, Part 1. - Int. J. LCA, 4(2), 66-74

DE HAES H.A.U., JOLLIET O., FINNVEDEN G., HAUSCHILD M., KREWITT W., MÜLLER-WENK R. (1999b) Best Available Practice Regarding Impact Categories and Category Indicators in Life Cycle Impact Assessment, Part 2. - Int. J. LCA, 4(3), 167-174

GREENPEACE (2011): Herbicide tolerance and GM crops - Why the world should be Ready to Round Up glyphosate.

IFEU (2011): GEF GreenHouse Gas Calculator, final version 30 November 2011. Developed by ifeu – Institut für Energie- und Umweltforschung Heidelberg GmbH within the GEF funded targeted research project "Global Assessments and Guidelines for Liquid Biofuels Production in Developing Countries". Download: http://www.unep.org/bioenergy/Portals/48107/doc/activities/GEF%20greenhouse%20gas%20calculator_FINAL.xls

IFEU (2012): $ENZO_2$ Greenhouse gas calculator - Ethanol from sugarcane, version 1.2 (January 2012). Developed by ifeu – Institut für Energie- und Umweltforschung Heidelberg GmbH, commissioned by the Federal Agency for Food and Agriculture (BLE).

MACHADO GERBER P., WALTER A. (2011): Socio-Economic Impacts of the Sugarcane chain in Brazil. Case study report (D 2.5) within the Global-Bio-Pact project 'Global Assessment of Biomass and Bioproduct Impacts on Socio-economics and Sustainability'.

MILLENNIUM ECOSYSTEM ASSESSMENT (2003): Ecosystems and Human Well-being: A Framework for Assessment. Island Press, Washington, DC.

MILLENNIUM ECOSYSTEM ASSESSMENT (2005): Ecosystems and Human Well-being: Synthesis. Island Press, Washington, DC.

OECD (2001): Poverty-Environment-Gender Linkages. Pre-print of the DAC Journal 2001, Volume 2, No. 4

RETTENMAIER, N., KÖPPEN, S., MÜNCH, J., BOTTRIELL, K., DIAZ-CHAVEZ, R. (2011): General environmental impacts, principles, criteria and indicators of biomass production and conversion. Deliverable D 5.1 within the Global-Bio-Pact project 'Global Assessment of Biomass and Bioproduct Impacts on Socio-economics and Sustainability'.

SAWE E.N., SHUMA J., PESAMBILI L.C. (2011): Socio-Economic Impacts of the Jatropha chain in Tanzania. Case study report (D 2.4) within the Global-Bio-Pact project 'Global Assessment of Biomass and Bioproduct Impacts on Socio-economics and Sustainability'.

SBARRA R., HILBERT J. (2011): Socio-Economic Impacts of the Soy Chain in Argentina. Case study report (D 2.2) within the Global-Bio-Pact project 'Global Assessment of Biomass and Bioproduct Impacts on Socio-economics and Sustainability'.

UNECA (2008): Sustainable Development Report on Africa.

VAN SLEEN, P., VIS, M., ABBAN-MENSAH, I., BOTTRIEL, K. (2011): Socio-economic impacts of second generation conversion technologies in Canada. Case study report (D 3.2) within the Global-Bio-Pact project 'Global Assessment of Biomass and Bioproduct Impacts on Socio-economics and Sustainability'.

WRIGHT A. (2011): Socio-Economic Impacts of the Palm oil chain in Indonesia. Case study report (D 2.3) within the Global-Bio-Pact project 'Global Assessment of Biomass and Bioproduct Impacts on Socio-economics and Sustainability'.

6 Annex

6.1 Environmental impacts

Life cycle assessment (LCA) usually addresses a number of environmental impact categories, such as the extraction of resources, land use, climate change or stratospheric ozone depletion (Table 6-1). All impact categories listed in this table and illustrated in Fig. 6-1 are considered baseline impact categories and should be covered in a LCA study.

Fig. 6-1 depicts the two approaches in LCA which either translate impacts into environmental themes such as climate change, acidification, or human toxicity (problem-oriented or midpoint approach) or into issues of concern / areas of protection such as human health, natural environment, and natural resources (damage-oriented or endpoint approach).

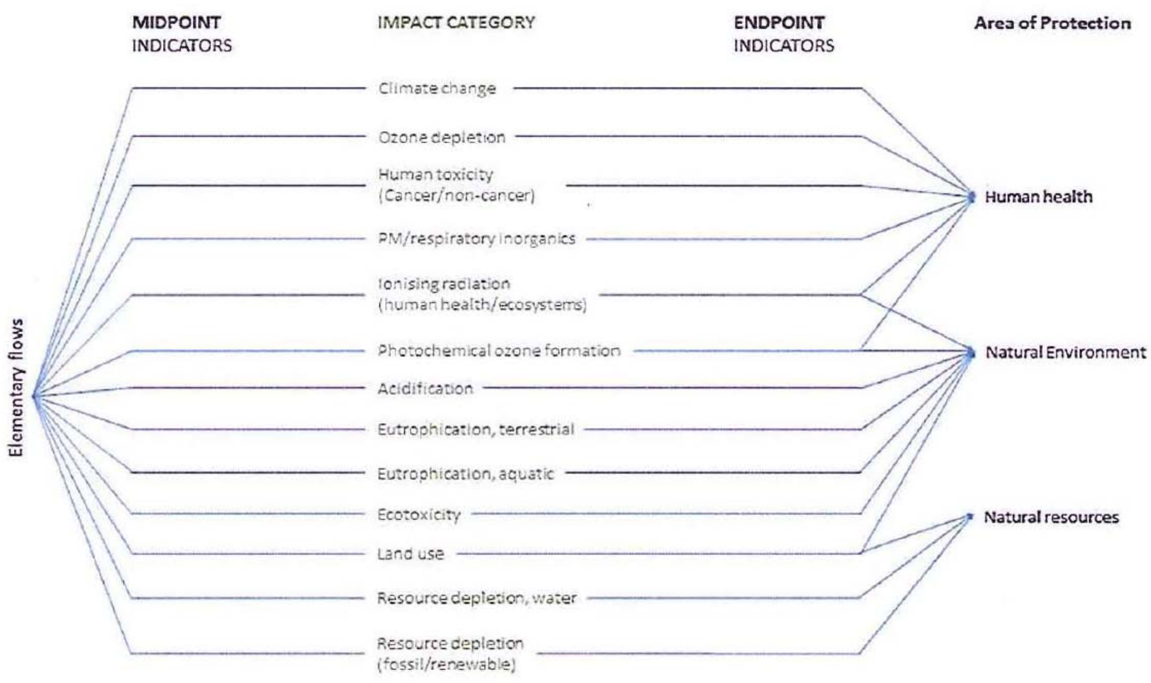

Fig. 6-1 Midpoint and endpoint Indicators towards Area of Protection (JRC 2011)

Table 6-1 List of impact categories – divided into input related and output related categories – incl. their content and area of protection (AoP) involved /de Haes et al. 1999b/. HH = Human health, NE = Natural environment, NR = Natural resources, MME = Man-made environment

Impact category	Content	AoP
Input related categories		
Extraction of abiotic resources	Extraction of different types of non-living material from the natural environment	NR
a) Non-renewable (depletable)	Fossil fuels, uranium / mineral ores	
b) Renewable (recoverable)	Water (except for fossil ground water)	
Extraction of biotic resources	Extraction of species types of biomass from the natural environment	NR, NE
Land use		
a) Increase of land competition	Physical interventions leading to exclusive land occupation, or to change in land occupation	NR
b) Degradation of life support systems	Degradation of processes in the natural environment which are due to land use and have broad regulation functions	NE
c) Biodiversity degradation	Impacts of physical interventions on biodiversity (ecosystems, species) as values in themselves	NE
Output related categories		
Climate change	All impacts related to climate change caused by changes in radiative forcing	HH, NE, MME
Stratospheric ozone depletion	All impacts due to stratospheric ozone depletion (incl. possible impacts on human health)	HH, NE, MME, NR
Human toxicity	All impacts on human health caused by direct emissions of toxic substances both outdoor and indoor, and impacts caused by fine particles and by radiation	HH
Eco-toxicity	All impacts on natural species and ecosystems caused by direct emissions of toxic substances, incl. degradation products thereof	NE, NR
Photo-oxidant formation	All impacts related to tropospheric oxidant formation, incl. impacts from NO_X emissions.	HH, MME, NE, NR
Acidification	All impacts due to acidification, incl. direct impacts on leaves, cation exchange in leaves and soil through ammonium, and mobilisation of Al and other toxic metals	NE, MME, HH, NR
Nutrification / eutrophication	All impacts of macro-nutrients on the vegetation, both natural as well as crops, both terrestrial as well as aquatic, and indirect effects thereof	NE, NR

6.2 GHG emissions from biofuel production and use

Among the environmental impacts investigated in Task 5.2 of the Global-Bio-Pact project, greenhouse gas (GHG) emissions are very important. It was decided to calculate GHG balances based on the case study data provided by the project partners. Since no deliverable report is connected to Task 5.2, the results of the GHG balances can be found in the following. IFEU decided to perform the GHG calculations according to the rules laid down in Annex V of the European Renewable Energy Directive (2009/28/EC, RED), since the Global-Bio-Pact project was initiated in order to evaluate if and in how far the current sustainability criteria (mainly environmental ones) can be supplemented by social sustainability criteria. Therefore, it seemed logical to use the methodology stipulated by the RED.

The RED contains so-called 'default values' for the GHG emissions associated with a number of liquid biofuels (mainly 1st generation biofuels). However, since the underlying basic data was not given in the Directive and the rules in given Annex V were interpreted differently, a number of GHG calculation tools emerged which produced different results for the same type of biofuel. Against this background, the BioGrace project was initiated which aims to harmonise calculations of biofuel greenhouse gas (GHG) emissions and thus supports the implementation of the EU Renewable Energy Directive (2009/28/EC) and the EU Fuel Quality Directive (2009/30/EC) into national laws. Within the project, a GHG calculator was developed covering all (1st generation) biofuels for which default values are listed in the RED. Out of the biofuels investigated in the Global-Bio-Pact project, the following ones are included in the RED and the BioGrace calculator:

- sugarcane ethanol
- soybean oil biodiesel
- palm oil biodiesel

For the calculation of the GHG emissions associated with sugarcane ethanol in Costa Rica, the 'ENZO$_2$ Greenhouse gas calculator' was used. The ENZO$_2$ calculator, commissioned by the German Federal Agency for Food and Agriculture (BLE) and developed by IFEU (IFEU 2012), is fully in line with the BioGrace calculator but offers more possibilities to customise the calculations. Such customisation was necessary for sugarcane ethanol in Costa Rica which is produced from molasses (and not from the sugar syrup as in the case of Brazil).

For the other biofuels investigated in the Global-Bio-Pact project (Jatropha biodiesel in Tanzania and Mali), yet another GHG calculator had to be used: the GEF 'Biofuel Green-House Gas Calculator'. This calculator was developed within the GEF funded targeted research project "Global Assessments and Guidelines for Liquid Biofuels Production in Developing Countries" (IFEU 2011) and contains a number of pre-defined settings. For the purpose of Global-Bio-Pact, this non-RED-conform calculator was modified to meet the rules laid down in Annex V of the RED.

In the following sections, the case study data provided by the project partners and used in the different calculators are documented. If no case study-specific data was available for some process steps, default values were taken.

Please note: since in all Global-Bio-Pact case studies, land-use changes did not occur **after 1 January 2008**, the term e_l (annualised greenhouse gas emissions from carbon stock change due to land-use change) was set zero.

Subsequently, the results of the GHG balances are presented. The GHG emissions from fuels are expressed in terms of:

- g CO_{2eq} / $MJ_{biofuel}$
- t CO_{2eq} / (ha*yr)

The first option is to be used in the context of the RED. According to the RED, the greenhouse gas emission saving from biofuels is calculated as:

SAVING = $(E_F – E_B)/E_F$,

where

E_B = total emissions from the biofuel or bioliquid; and

E_F = total emissions from the fossil fuel comparator.

The resulting percentage is expressing the **relative** savings achieved by the biofuel compared to the fossil fuel comparator. The RED sets a minimum threshold of 35 %.

The second option is not used in the context of the RED. Instead of being related to a unit of energy, the emissions are related to a unit of area, shifting the focus on land use efficiency. IFEU and other LCA experts prefer to use this option; moreover we prefer to calculate the **net** (or absolute) greenhouse gas emission savings as:

SAVING = E_B - E_F

This is what really matters in terms of mitigation of climate change.

6.2.1 GHG emissions from soybean oil biodiesel in Argentina

Case study data

Soybean cultivation and transport:

	Ven. Tuerto	Pergamino	Rio Cuarto	Viluco
Yield [kg ha^{-1} year^{-1}]	4,500	3,600	2,750	3,122.47
Diesel [MJ ha^{-1} year^{-1}]	998	998	998	1,049.83
N-fertiliser [kg ha^{-1} year^{-1}]	14	4.4	-	1.98
K_2O-fertiliser [kg ha^{-1} year^{-1}]	-	-	-	-
P_2O_5-fertiliser [kg ha^{-1} year^{-1}]	78	21	-	16.35
Avg. distance field - conversion facility [km]	191	139.9	395	354.33

Soybean conversion (same data for all case studies):

	Case studies 1-3	Viluco
Extraction of oil		
Yield of soybean oil [MJ_{oil} / $MJ_{soybean}$]	0.3020	0.2865
Electricity EU mix [MJ / MJ_{oil}]	0.0040	0.0231
Steam (from NG boiler) [MJ / MJ_{oil}]	0.150014	0.1414
n-Hexane [MJ / MJ_{oil}]	0.0001	0.0056
Transesterification		
Yield of FAME [MJ_{FAME} / MJ_{oil}]:	0.966	0.966
Co-product refined glycerol [kg / ton FAME]	126.3	125.1
Electricity EU mix [MJ / MJ_{FAME}]	0.0034	0.0035
Steam (from NG boiler) [MJ / MJ_{FAME}]	0.0403	0.0204
Methanol [MJ / MJ_{FAME}]	0.0557	0.064

Please note: the BioGrace calculator (and the RED Default value) is based on the assumption that soybeans are transported to Europe and processed there. In reality, soybean oil is nowadays extracted in Argentina and converted to biodiesel, which is then shipped to Europe.

Results

Fig. 6-1 shows the GHG emissions related to soybean oil biodiesel production and use in Argentina as calculated according to the rules laid down in Annex V of the RED. In all cases, soybean oil biodiesel fulfils the minimum threshold of 35 % (relative to the fossil fuel comparator), i.e. they are below the red line. The GHG emission savings amount to almost 60 %. The results are much better compared to the default value of the RED (31 %).

If emission saving from soil carbon accumulation (e_{sca}) via improved agricultural management (e.g. no-tillage system) was taken into account, the GHG emission savings would increase to about 75 % – 85 %. However, the RED stipulates that 'the reference land use shall be the land use in January 2008 or 20 years before the raw material was obtained, whichever was the later.' This means that in the case of soybean oil biodiesel production in Argentina, the reference land use would be the land use in January 2008. Assuming that the no-tillage system was introduced long before January 2008, no changes in land carbon stocks could be accounted for, i.e. the term e_{sca} would be zero and the grey dotted bar (improved agricultural management) in Fig. 6-1 would disappear.

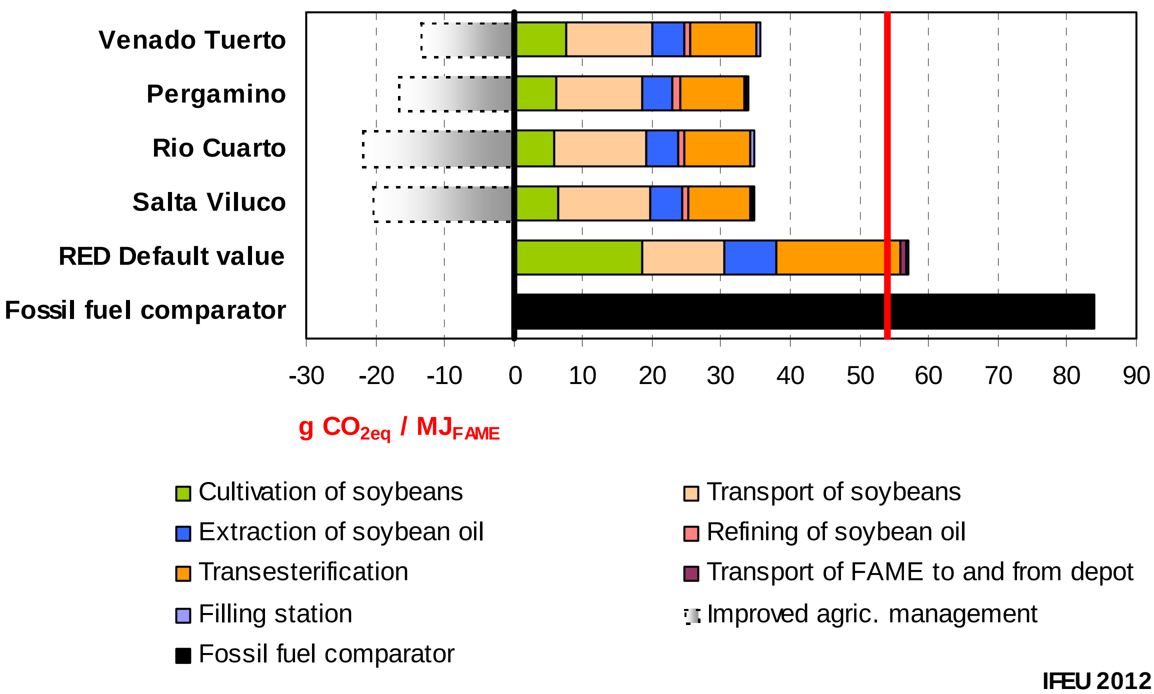

Fig. 6-1 GHG emissions from soybean oil biodiesel in Argentina compared to its fossil fuel comparator according to the rules laid down in Annex V of the RED (IFEU based on Sbarra & Hilbert 2011)

Fig. 6-2 shows the net greenhouse gas emission savings ranging from 0.75 – 1.2 t CO_{2eq} per hectare and year. The results reflect differences in soybean yield per hectare much more than the results displayed in Fig. 6-1. Please note that as mentioned above, emission savings from soil carbon accumulation via improved agricultural management (grey dotted bar) were not taken into account, assuming that the no-tillage system was introduced before January 2008.

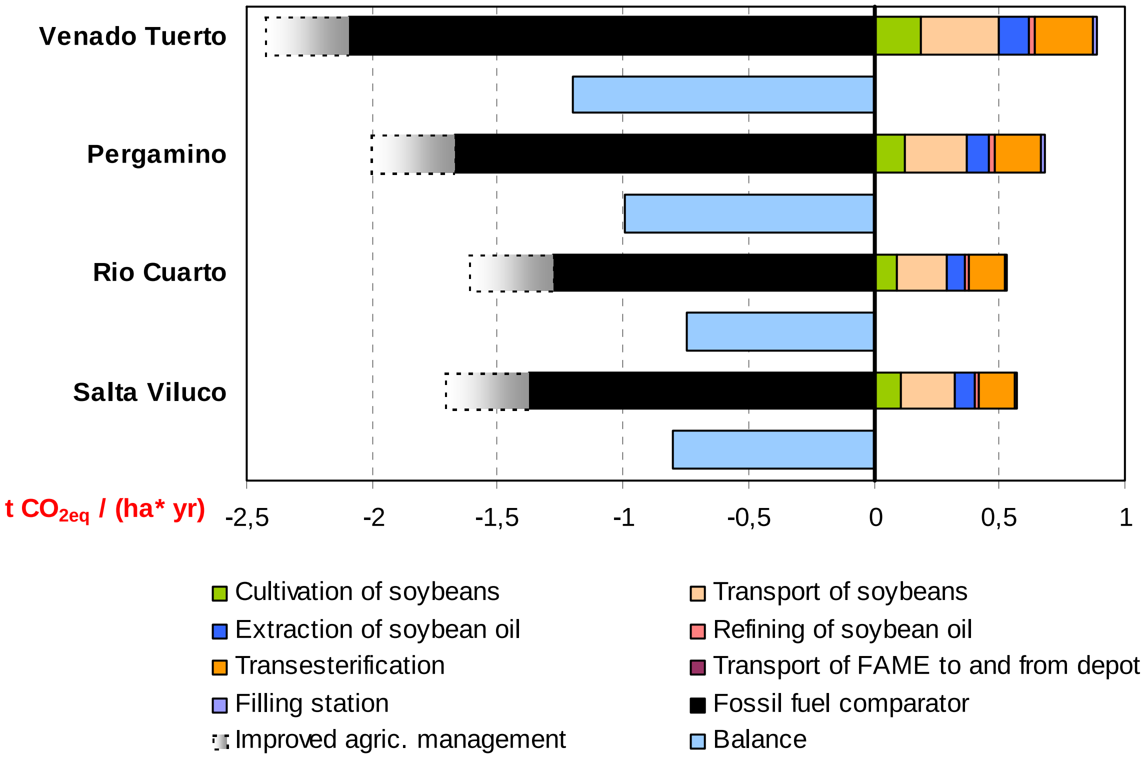

Fig. 6-2 GHG emissions per hectare and year from the production of soybean oil biodiesel in Argentina compared to its fossil fuel comparator (IFEU based on Sbarra & Hilbert 2011). The light blue 'Balance' bar shows the net GHG emission savings.

6.2.2 GHG emissions from sugarcane bioethanol in Brazil

Case study data

Sugarcane cultivation and transport:

Yield [kg ha^{-1} $year^{-1}$]	70,000
Diesel [MJ ha^{-1} $year^{-1}$]	302
N fertiliser [kg ha^{-1} $year^{-1}$]	80
CaO fertiliser [kg ha^{-1} $year^{-1}$]	364
Filter mud cake [kg ha^{-1} $year^{-1}$]	568
K_2O fertiliser [kg ha^{-1} $year^{-1}$]	83
P_2O_5 fertiliser [kg ha^{-1} $year^{-1}$]	16
Pesticides [kg ha^{-1} $year^{-1}$]	0.2
Vinasse [kg ha^{-1} $year^{-1}$]	56,802

Sugarcane conversion:

Ethanol yield [$MJ_{ethanol}$ / $MJ_{sugarcane}$]	0.268

Results

Fig. 6-3 shows the GHG emissions related to sugarcane bioethanol production and use in Brazil. The RED minimum threshold of 35 % is fulfilled. The GHG emission savings amount to 73 %, which is similar to the default value of the RED (71 %). Fig. 6-4 shows the net greenhouse gas emission savings of around 3 t CO_{2eq} per hectare and year. The reduction of greenhouse gas emissions per hectare and year is the highest of all crops investigated in this project. This means that sugarcane for bioethanol in Brazil uses the cultivated area most efficiently for reducing the greenhouse gas emissions.

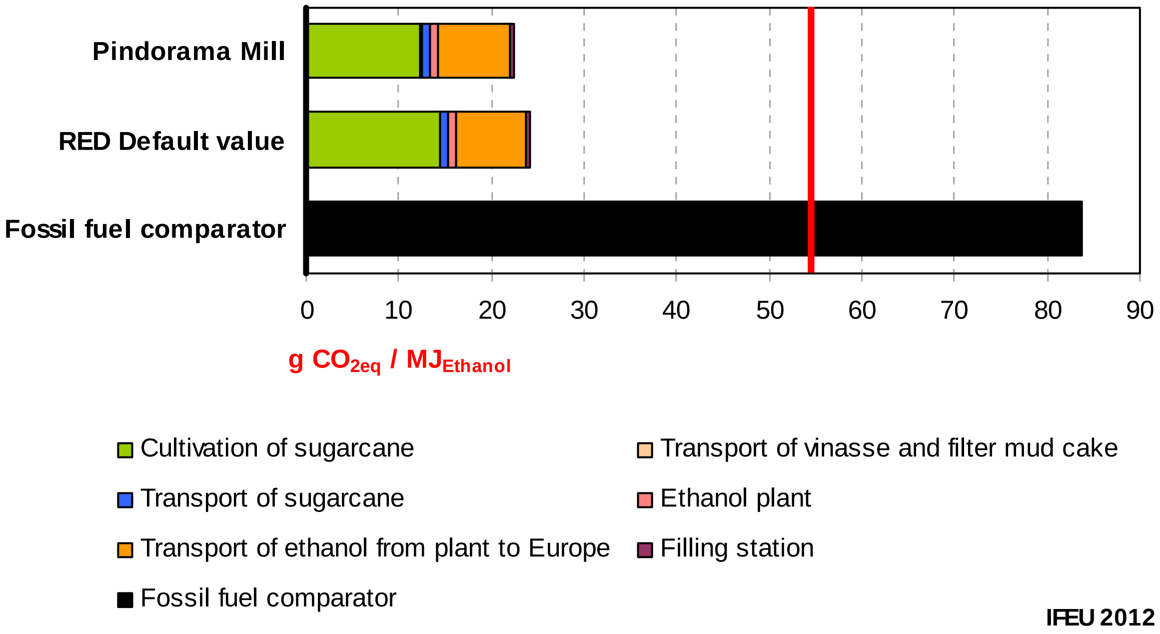

Fig. 6-3 GHG emissions from sugarcane bioethanol in Brazil compared to its fossil fuel comparator (IFEU based on Machado & Walter 2011)

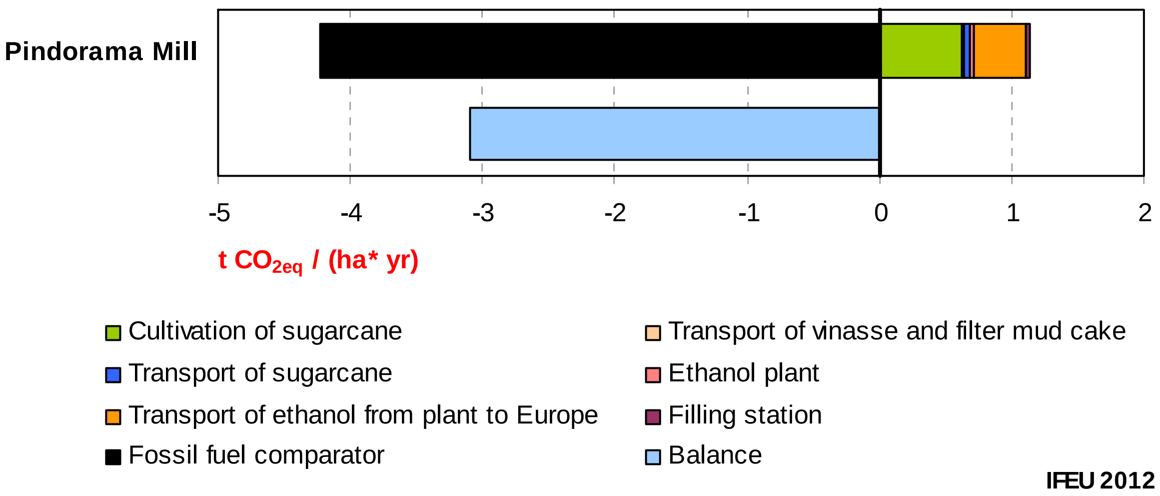

Fig. 6-4 GHG emissions per hectare and year from sugarcane bioethanol in Brazil compared to its fossil fuel comparator (IFEU based on Machado & Walter 2011). The light blue 'Balance' bar shows the net GHG emission savings.

6.2.3 GHG emissions from sugarcane molasses bioethanol in Costa Rica

Case study data

Sugarcane cultivation and transport:

Yield [kg ha^{-1} $year^{-1}$]:	87,400
N fertiliser [kg ha^{-1} $year^{-1}$]	176.4[5]
CaO fertiliser [kg ha^{-1} $year^{-1}$]	1,073.5
K_2O fertiliser [kg ha^{-1} $year^{-1}$]	133.7
P_2O_5 fertiliser [kg ha^{-1} $year^{-1}$]	117.5
Pesticides [kg active ingredient ha^{-1} $year^{-1}$]	12.7

Sugarcane conversion (ethanol plant):

	CATSA	**Purchased**
Sugarcane processed [t $year^{-1}$]	657,000	-
Molasses [t $year^{-1}$]	24,966	16,834
Ethanol yield [t $year^{-1}$]	5,217	3,517
Co-products produced		
Sugar [t $year^{-1}$]	65,700	-
Rum [t $year^{-1}$]	26,280	-
Vinasse [t $year^{-1}$]	72,270	48,730

Results

Fig. 6-5 shows the GHG emissions related to bioethanol production from (sugarcane) molasses in Costa Rica. The reduction of greenhouse gas emissions of 75 % is well above the 35 % minimum threshold of the RED. There is no default value for ethanol from molasses yet. Fig. 6-6 shows the net greenhouse gas emission savings of approximately 1,2 t CO_{2eq} per hectare and year.

5 Amount is about 3 times higher than the RED default value (62.5 kg N ha^{-1} $year^{-1}$)

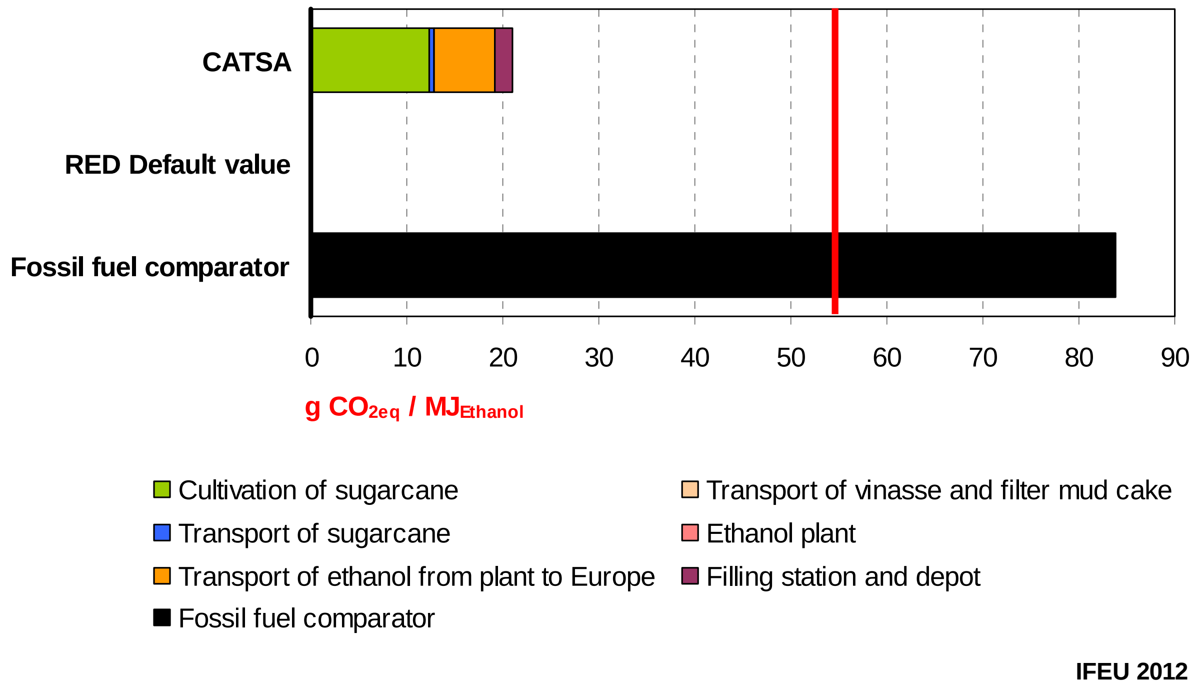

Fig. 6-5 GHG emissions from (sugarcane) molasses bioethanol in Costa Rica compared to its fossil fuel comparator (IFEU based on Cárdenas & Fallot 2011)

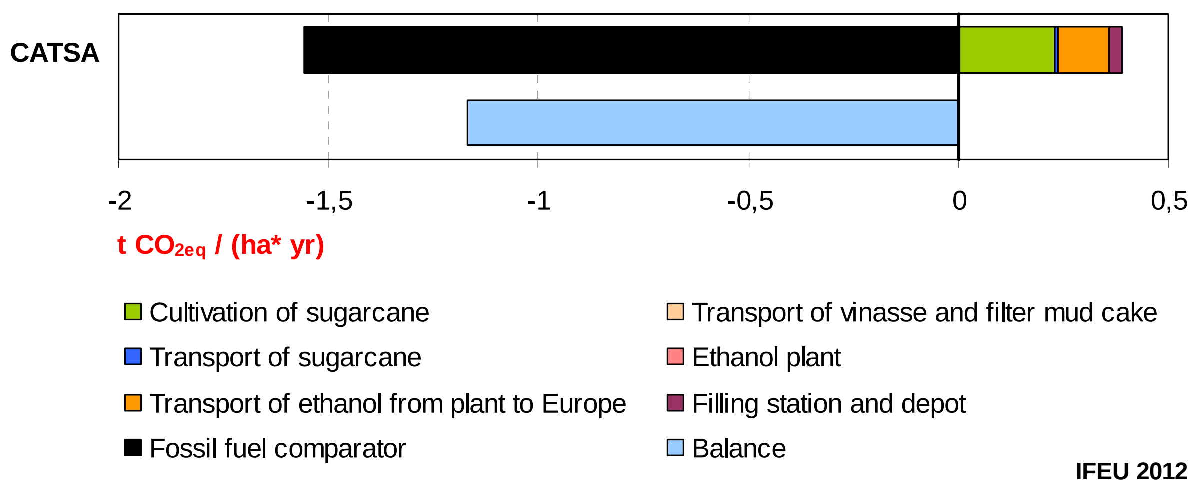

Fig. 6-6 GHG emissions per hectare and year from (sugarcane) molasses bioethanol in Costa Rica compared to its fossil fuel comparator (IFEU based on Cárdenas & Fallot 2011). The light blue 'Balance' bar shows the net GHG emission savings.

6.2.4 GHG emissions from palm oil biodiesel in Indonesia

Case study data

Palm oil cultivation and transport:

	Aek Raso Plantation	**Desa Asam Jawa**	**Harapan Makmur**
Yield [kg ha^{-1} $year^{-1}$]	18,860	13,584	9,600
N fertiliser [kg ha^{-1} $year^{-1}$]	76.2	108.8	130.8
CaO fertiliser [kg ha^{-1} $year^{-1}$]	166	180.3	73.2
K_2O fertiliser [kg ha^{-1} $year^{-1}$]	111.8	496.5	126
P_2O_5 fertiliser [kg ha^{-1} $year^{-1}$]	61	207.5	-
Avg. distance field - conversion facility [km]	< 5	7	75

Palm oil conversion (same data for all case studies):

Extraction of oil

Yield of palm oil [MJ_{oil} / MJ_{FFB}]	0.1796
Co-product kernel meal [$MJ_{kernel\ meal}$ / MJ_{FFB}]	0.0132
n-Hexane [MJ / MJ_{oil}]	1.2 E-09

Results

Fig. 6-7 shows the GHG emissions related to palm oil biodiesel production Indonesia. None of the three case studies reaches the 35 % minimum threshold of the RED. This is mainly due to the fact that the methane emissions from the palm oil mill effluent (POME) treatment are not captured. Due to the importance of this process step, there are two default values in the RED for oil mills with methane capture (36 %) and without methane capture (19 %). All case studies are below the default value, only Desa Asam Jawa case (16 %) is getting somewhat close to it. Another reason for failing to meet the RED minimum threshold is the relatively high amount of fertilisers applied.

Fig. 6-8 shows the net greenhouse gas emission savings ranging from 0.4 – 1.4 t CO_{2eq} per hectare and year. It is worth noting that despite failing to meet the RED minimum threshold, the GHG balances indicate net GHG emission savings which are in the same order of magnitude as for soybean oil biodiesel. Of course, they could be considerably higher since palm oil yields per hectare and year are almost 10 times higher than soybean oil yields. The low performance of palm oil biodiesel is again explained by the methane emissions from POME treatment and the relatively high fertiliser application rates.

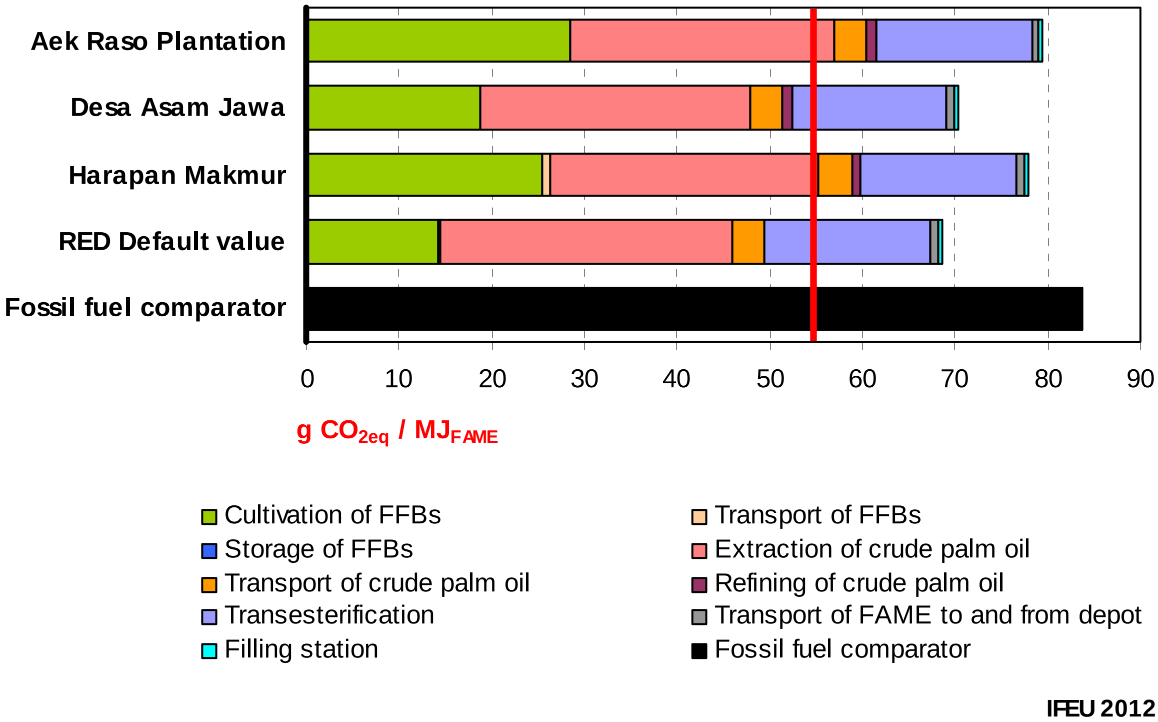

Fig. 6-7 GHG emissions from palm oil biodiesel in Indonesia compared to its fossil fuel comparator (IFEU based on Wright 2011)

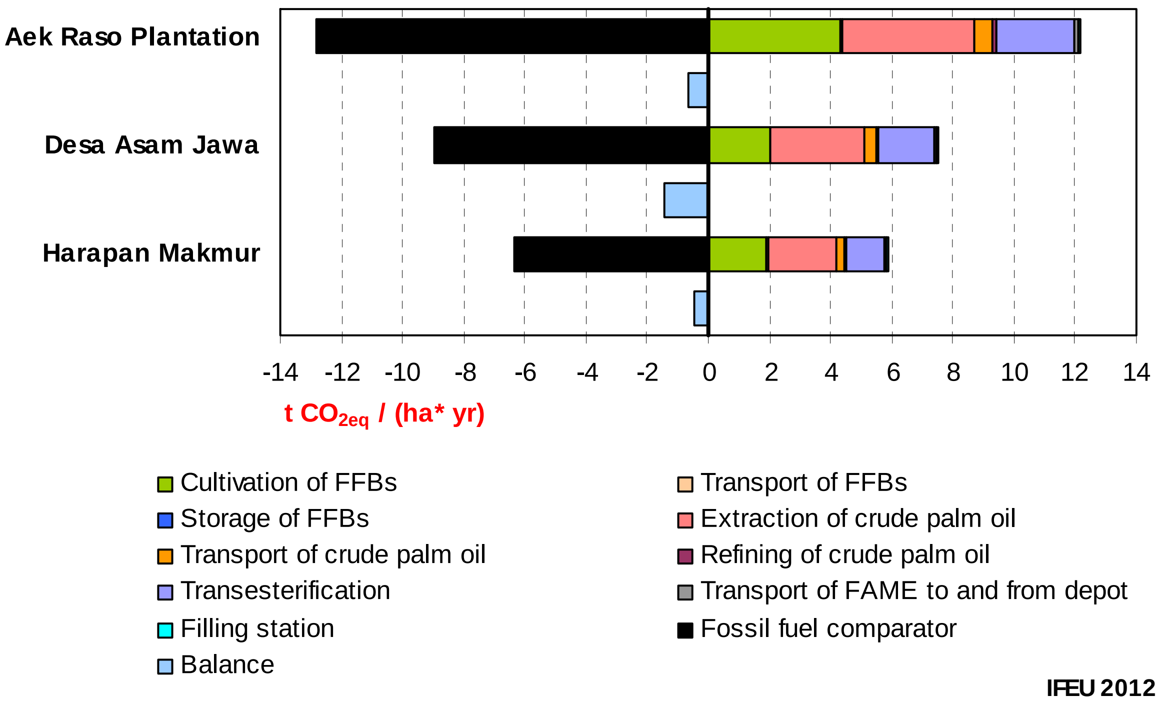

Fig. 6-8 GHG emissions per hectare and year from palm oil biodiesel in Indonesia compared to its fossil fuel comparator (IFEU based on Wright 2011). The light blue 'Balance' bar shows the net GHG emission savings.

6.2.5 GHG emissions from Jatropha oil biodiesel in Tanzania

Case study data

Greenhouse gas emissions from Jatropha cannot be calculated with the BioGrace calculator. For the calculation within this project, the GEF 'Biofuel GreenHouse Gas Calculator' was used instead (IFEU 2011). Due to a lack of case study related data, predefined data of the calculator for Tanzania was modified to meet the rules laid down in Annex V of the RED.

Results

Fig. 6-9 show the GHG emissions related to Jatropha biodiesel in Tanzania. The first scenario ('plantation') can be regarded as a worst case. It does not fulfil the 35 % minimum threshold of the RED. This is mainly due to the high input cultivation system, which is contributing most to the negative result.

Fig. 6-10 shows the net GHG emission savings ranging from 0.4 – 0.6 t CO_{2eq} per hectare and year. The results reflect differences in Jatropha yield per hectare: the 'smallholder, low input, marginal land' setting shows the smallest yield resulting in the lowest savings of GHG emissions per hectare and year. The higher yield of the plantation is almost entirely compensated by the high expenditures for the cultivation of the crop. Thus, the plantation scheme has only got slightly higher GHG emission reductions per hectare and year than the smallholder scheme with intermediate input.

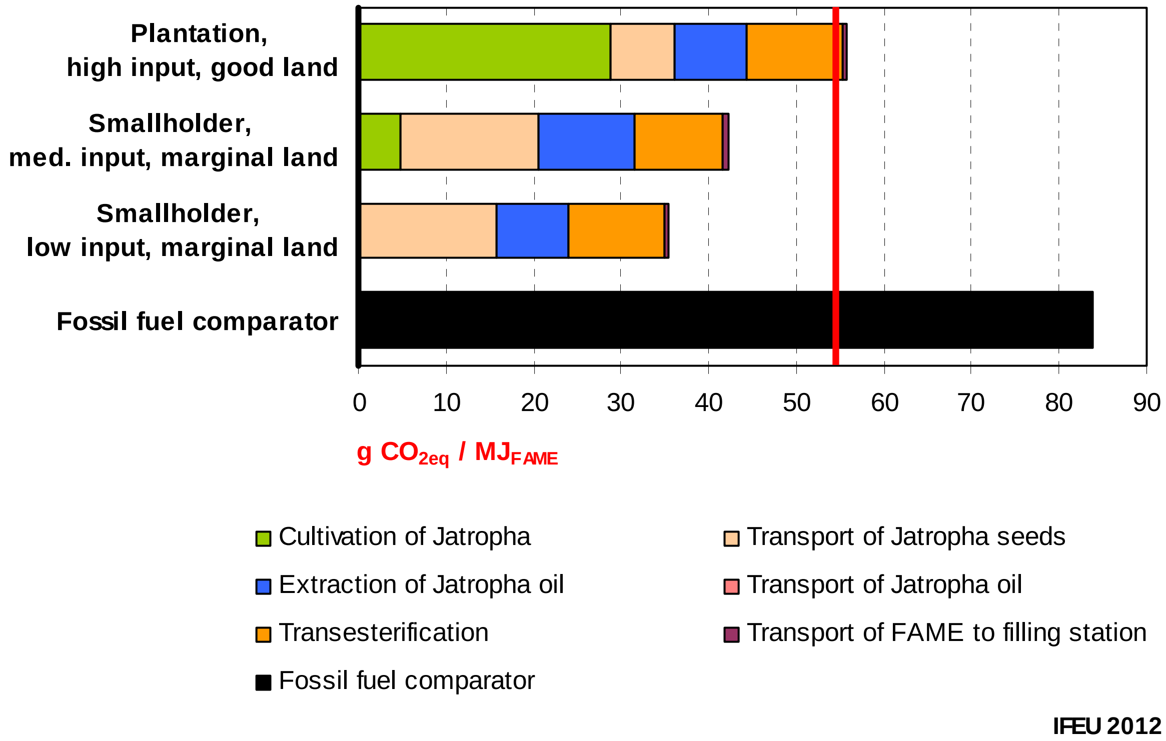

Fig. 6-9 GHG emissions from Jatropha biodiesel in Tanzania compared to its fossil fuel comparator (IFEU based on Sawe et al. 2011)

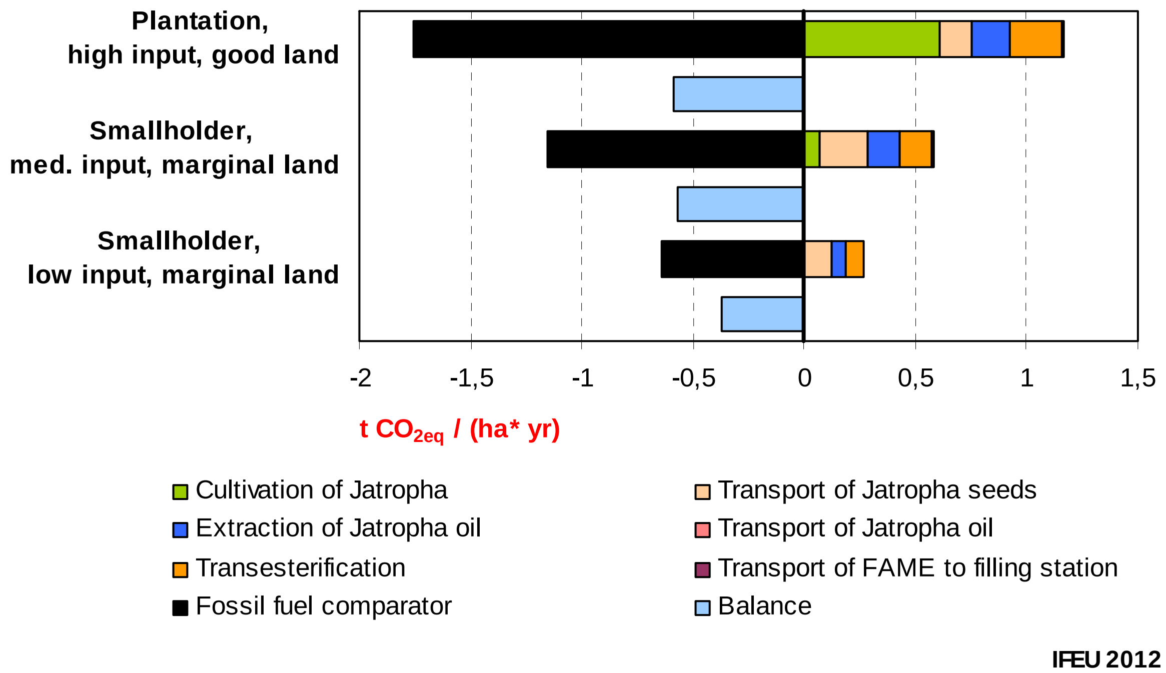

Fig. 6-10 GHG emissions per hectare and year from Jatropha biodiesel in Tanzania compared to its fossil fuel comparator (IFEU based on Sawe et al. 2011). The light blue 'Balance' bar shows the net GHG emission savings.

6.2.6 GHG emissions from Jatropha oil biodiesel in Mali

Case study data

Greenhouse gas emissions from Jatropha cannot be calculated with the BioGrace calculator. For the calculation within this project, the GEF 'Biofuel GreenHouse Gas Calculator' was used instead (IFEU 2011). Due to a lack of case study-related data, mainly predefined data of the calculator for Mali was used and modified to meet the rules laid down in Annex V of the RED. The Smallholder, low input system is closest to the situation of the Malian case study. No Diesel was used for the transport of the seeds and the FAME was used on site. Therefore, no GHG emissions are associated with transport.

Results

Fig. 6-11 shows the GHG emissions from Jatropha biodiesel in Mali. Both schemes lead to GHG emission savings of more than 35 %. Until now, there is no default value for Jatropha biodiesel. Fig. 6-12 shows the net GHG emission savings. The values around 0.4 t CO_{2eq} per hectare and year are rather low, which is mainly due to the low yields in Mali.

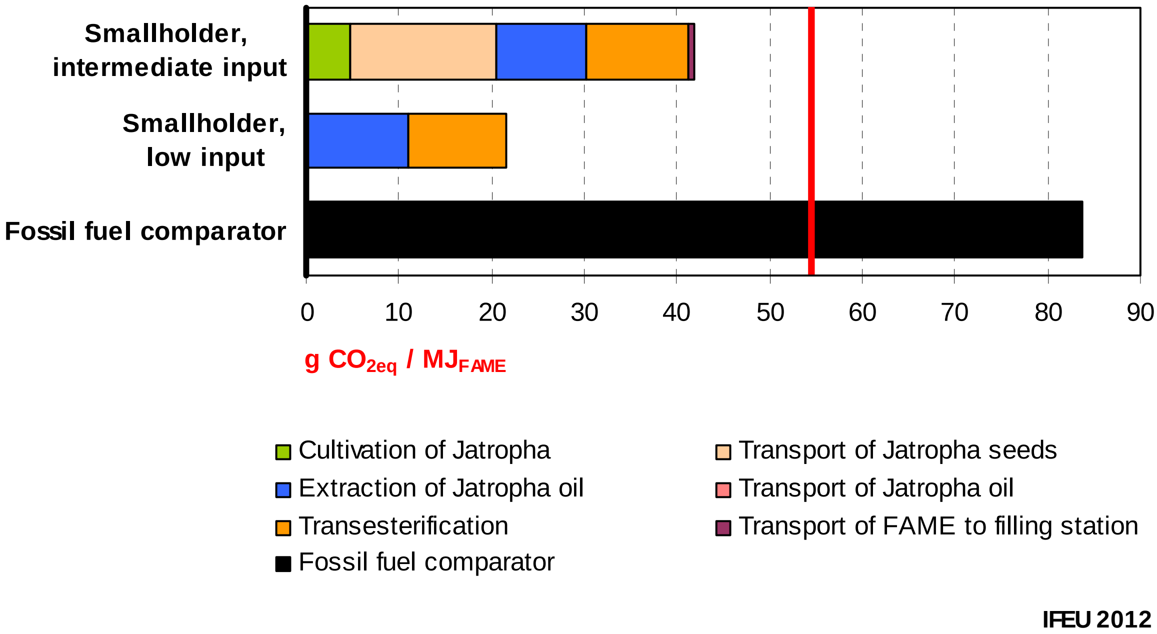

Fig. 6-11 GHG emissions from Jatropha biodiesel in Mali compared to its fossil fuel comparator (IFEU based on Burrell et al. 2011)

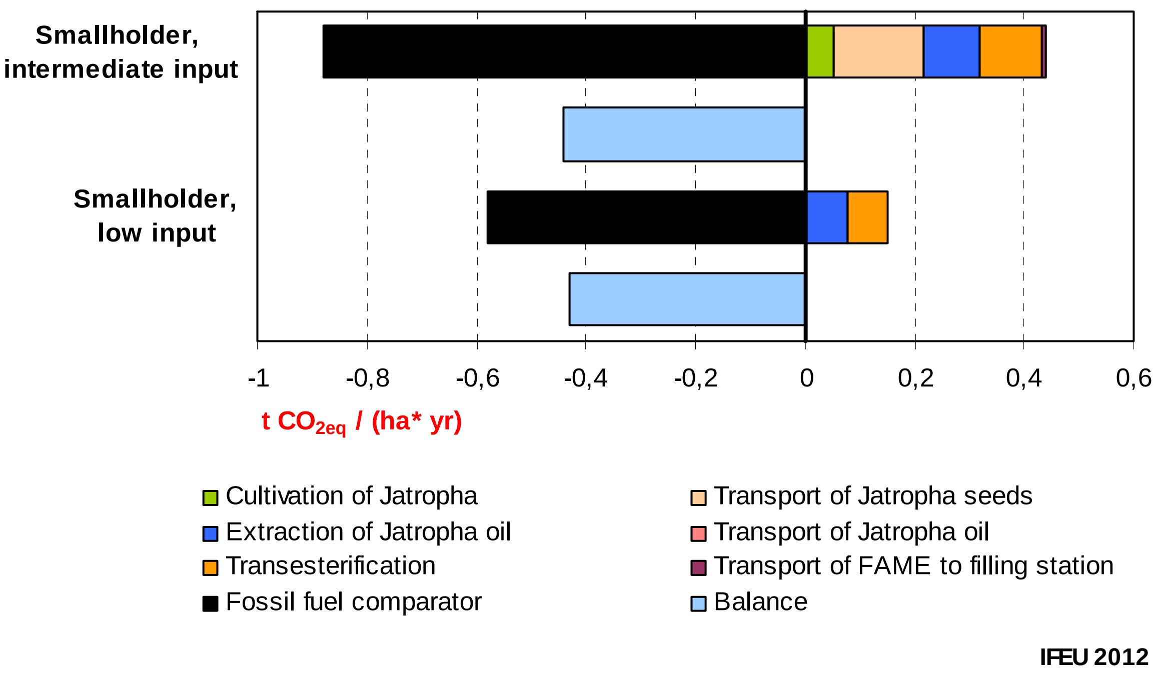

Fig. 6-12 GHG emissions per hectare and year from Jatropha biodiesel in Mali compared to its fossil fuel comparator (IFEU based on Burrell et al. 2011). The light blue 'Balance' bar shows the net GHG emission savings.