Chapter 4
Linkages Between Socio-Economic and Environmental Impacts of Bioenergy

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Abstract In the light of a controversial discussion on the net benefit of biofuels and bioenergy, the European Renewable Energy Directive (2009/28/EC, RED)—which sets out a mandatory target for the share of renewable energy in the transport sector (10 % by 2020)—has established a number of mandatory sustainability criteria, which biofuels and bioliquids have to meet to be able to be counted towards the target. However, these mandatory sustainability criteria so far only address selected environmental impacts (greenhouse gas (GHG) emissions and biodiversity) and omit impacts on soil, water, and air as well as GHG emissions due to indirect land-use change (iLUC). Social and socio-economic impacts are not covered at all. The latter gap was addressed by the EU-FP7-funded Global-Bio-Pact project. The project's main aim was to improve and harmonize global sustainability certification systems for biomass production, conversion systems and trade in order to prevent negative socio-economic impacts. Within the project, linkages between socio-economic and environmental impacts of biofuels/bioenergy and bio-based products were analyzed in order to avoid an increase of negative environmental impacts while trying to prevent negative socio-economic impacts. After an introduction and some insights into the environmental impacts of biofuels/bioenergy and bio-based products, this chapter presents the results of a SWOT analysis (analysis of strengths, weaknesses, opportunities, and threats), revealing trade-offs as well as positive and negative correlations between socio-economic and environmental impacts. These linkages are subsequently interpreted using the concept of ecosystem services. Finally, conclusions are drawn and a recommendation is made how the current list of mandatory sustainability criteria in the RED could be amended.

Keywords Environmental impacts · Socio-economic impacts · Bioenergy · Biofuel · SWOT analysis · Positive correlations · Negative correlations · Trade-offs · Ecosystem services · Sustainability criteria

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4.1 Introduction

In many parts of the world, climate change and concerns of security of supply are the main drivers for the promotion of the use of renewable resources. One of the main pillars of most strategies to mitigate climate change and save nonrenewable resources is the use of biomass for energy. In several countries, strong incentives have been put in place to increase the use of biomass for energy both in the transport as well as in the energy supply sector (heat and/or power generation), mainly in the form of mandatory targets (U.S. Congress 2007), (EP and CEC 2009). Many countries have successfully implemented policies to foster biofuels and bioenergy, including tax exemptions or relief, feed-in tariffs, or quotas. On the contrary, much less attention has been paid to the use of biomass for bio-based products, despite considerable potentials to mitigate greenhouse gas emissions and to save nonrenewable resources (Rettenmaier et al. 2010a, b). Nevertheless, the demand for industrial crops for biochemicals and biomaterials is expected to increase in the future since biomass is the only renewable source of carbon.

Taken together, these nonfood biomass crops will put additional pressure on global agricultural land (Bringezu et al. 2009). At the same time, world population growth (projected to reach 9.3 billion people by 2050 according to UN (2011)) and changing diets due to economic development lead to an additional demand for land for food and feed production. As a consequence, the already existing competition for land for the production of food, feed, fiber (bio-based products), fuel (biofuels and bioenergy), and ecosystem services[1] might even aggravate over the next decades. Concerns have been raised both in terms of social and environmental impacts because land use competition might i) jeopardize food security (Eickhout et al. 2007) and give rise to social conflicts, ii) result in an intensified use of existing agricultural land, or iii) lead to an expansion of agricultural land, most likely at the cost of (semi)natural ecosystems being converted into cropland. Several studies have pointed out the negative implications of such direct and indirect land-use changes, among others in terms of biodiversity loss and greenhouse gas emissions (Searchinger et al. 2008; Fargione et al. 2008; Gibbs et al. 2008; Gallagher 2008; Melillo et al. 2009; Ravidranath et al. 2009).

In the light of a controversial discussion on the net benefit of biofuels and bioenergy, the European Renewable Energy Directive (2009/28/EC, RED) (EP and CEC 2009)—which sets out a mandatory target for the share of renewable energy in the transport sector (10 % by 2020)—has established a number of mandatory sustainability criteria, which biofuels and bioliquids have to meet to be able to be counted towards the target (Articles 17(2) to 17(6)):

- **Climate change-related criteria**: The greenhouse gas emission (GHG) saving from the use of biofuels and bioliquids—including emission from direct land-use

[1] 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 (see Sect. 4.3).

changes (dLUC)—shall be at least 35 % compared to the fossil fuel comparator (Article 17(2)). From 2017 and 2018, the GHG emission saving shall be at least 50 % and 60 %, respectively. Further details are found in Article 19 and Annex V (rules for calculating the GHG impact).

- **Land cover-related criteria**: Biofuels and bioliquids shall not be made from raw material obtained from land that in or after January 2008 had the status of i) land with high biodiversity value such as primary forest, protected areas, or highly biodiverse grassland[2] (Article 17(3)), ii). land with high carbon stock such as wetlands or continuously forested areas (Article 17 (4)), or iii). peatland (Article 17(5)).
- **Cultivation-related criteria**: Agricultural raw materials cultivated in the Community shall be obtained in accordance with the common rules for direct support schemes for farmers (Cross Compliance) under the common agricultural policy and in accordance with the minimum requirements for good agricultural and environmental condition (Article 17(6)).

The mandatory sustainability criteria listed above—which so far only have to be met by liquid biofuels and bioliquids (but not by solid and gaseous biofuels or bio-based products)—only address selected environmental impacts (GHG emissions and biodiversity) and omit impacts on soil, water, and air as well as GHG emissions due to indirect land-use change (iLUC). Social/socio-economic impacts are not covered at all by the list of mandatory sustainability criteria.

In addition, the RED sets out a number of reporting obligations by the European Commission to the European Parliament, but these are no mandatory criteria to be met by biofuels and bioliquids. The Commission shall, every two years from 2012 onwards, report (Article 17(7)):

- On national measures taken to respect the sustainability criteria set out in Articles 17(2) to 17(5) and for soil, water, and air protection
- On the impact on social sustainability in the Community and in third countries
- On the impact on the availability of foodstuffs at affordable prices, in particular for people living in developing countries
- On the respect of land-use rights
- Whether the countries that are a significant source of raw material have ratified and implemented the core Conventions of the International Labour Organization (ILO)
- Whether these countries have ratified and implemented the Cartagena Protocol on Biosafety and the Convention on International Trade in Endangered Species (CITES)

The aim of this chapter is to reveal trade-offs as well as positive and negative correlations between socio-economic and environmental impacts. This way,

[2] Protected areas and nonnatural highly biodiverse grassland may be used provided that the raw material production does not interfere with nature protection purposes and that the harvesting of the raw material is necessary to preserve its grassland status, respectively. Primary forests and natural highly biodiverse grassland, however, may not be used at all.

opportunities to minimize negative and optimize positive impacts on both the environment as well as social and economic situations are identified. Moreover, the aim is to explore whether and how the current list of sustainability criteria in the RED can be amended by mandatory socio-economic sustainability criteria and how this would impact on the environmental sustainability criteria.

4.2 Environmental Impacts of Biofuels and Bio-Based Products

4.2.1 General Environmental Impacts of Biofuels and Bio-Based Products

Biofuels, bioenergy, and bio-products are generally considered to be environmentally friendly since they save nonrenewable energy resources, are biodegradable and—at least at first glance—CO_2 neutral. The latter is of course only true for the direct combustion of biofuels which releases the same amount of CO_2 into the atmosphere that earlier has been taken up by the plants. However, when looking at the entire life cycle of biofuels it becomes clear that biofuels are neither CO_2 neutral nor environmentally friendly per se.

Like with any other product, a number of environmental impacts are usually associated with the production and use of biomass for bioenergy or biomaterial purposes. These 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 (nonrenewable energy carriers and minerals), and on man-made environment.

Different techniques exist to assess the environmental impacts associated with a product or an activity. In general, environmental assessment techniques have been developed since the 1970s to ensure the identification, analysis, and consideration of environmental impacts before the regarded product or activity is launched (ex ante analysis). Environmental assessment therefore represents an integrative tool combining the consideration of potential environmental impacts and public concern and allows comprehensive decision-making.

There are several environmental management techniques such as product carbon footprint (PCF), life cycle assessment (LCA), eco-audit, environmental impact assessment (EIA), and strategic environmental assessment (SEA). Each of these techniques is appropriate for specific situations. Not only do they differ in the subject of study (product, production site, project, or law), but also in their ability to address environmental impacts occurring at different spatial levels.

Life cycle assessment (LCA), for example, addresses the environmental aspects and potential environmental impacts (e.g. use of resources and the environmental consequences of releases) of a product throughout its life cycle.

Although methodological developments are under way, LCA is still considered weak regarding local environmental impacts which are not yet covered in standard LCA studies.

Environmental impact assessment (EIA), on the contrary, is specifically designed to assess projects. It typically addresses the following environmental impact categories: soil, water, air, biological resources, landscapes, and visual impacts, as well as the physical factor of the impact (e.g. noise). Regarding bioenergy and bio-based products, studies focusing on local environmental impacts use elements of EIA and cover aspects connected to the cultivation of the respective feedstock. The considered impact categories are therefore mainly biodiversity, soil, and water (e.g., Fernando et al. 2010).

Within the Global-Bio-Pact project a review of existing studies on environmental impacts of bioenergy and bio-based products was performed (Rettenmaier et al. 2011). For this purpose, two assessment techniques were selected: life cycle assessment (LCA) and elements of environmental impact assessment (EIA). The latter were preferred over strategic environmental assessment (SEA) (EP and CEC 2001), since the case studies within the Global-Bio-Pact project are focussing on specific examples of biomass production and conversion (i.e. projects) rather than on (biofuel) policies, plans, or programs. For more information regarding SEA of biofuels, the reader is referred to a recent OECD publication (OECD 2011).

The main conclusion derived from this review (Rettenmaier et al. 2011) is that biofuels/bioenergy and bio-based products are mainly associated with land use impacts and related impacts on the natural environment and resources. A short summary of the most important aspects is given in the following list:

- **Greenhouse gas emissions**: In recent years, several studies have pointed out that the greenhouse gas balance (carbon footprint) of biofuels/bioenergy is only positive as long as no major changes in land carbon stocks occur, e.g. caused by direct and indirect land-use changes.
- **Biodiversity**: Biodiversity is threatened by two different mechanisms: intensification of production on existing agricultural land (high inputs, monocultures etc.) and expansion of agricultural land (i.e. land use changes) at the cost of (semi)natural ecosystems. The impacts strongly depend on location, agricultural practices, and previous land use.
- **Water**: Two aspects related to water are discussed in the context of biofuels/bioenergy and bio-based products: water quality and water quantity. Biomass cultivation and conversion may lead to water pollution/contamination and depletion of (scarce) water resources.
- **Soil**: Biomass cultivation—like other agricultural activities—may have negative impacts on soil physical, chemical, and biological properties, including soil erosion (by water and wind), soil organic matter (SOM) decline, soil compaction, and salinization.

These most important aspects are mentioned by the FAO-funded Bioenergy Environmental Impact Analysis (BIAS) project (Fritsche et al. 2010) and classified according to the spatial level (global/ regional/ local) at which they are occurring

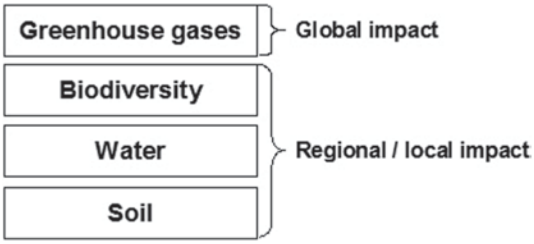

Fig. 4.1 Key modules of the BIAS framework (Adapted from Fritsche et al. 2010)

(Fig. 4.1). The BIAS project provides a framework for assisting decision-makers and stakeholders in comparing the environmental impacts of competing bioenergy development options. These main areas of concern are also reflected in the European Renewable Energy Directive (2009/28/EC, RED) (EP and CEC 2009). Article 23(1) of the RED specifically mentions the impacts on global warming (greenhouse gas emissions), biodiversity, water resources quality, and soil quality (EP and CEC 2009).

4.2.2 Environmental Impacts Associated with the Global-Bio-Pact Case Studies

Within the Global-Bio-Pact project seven in-depth case studies investigated the cultivation and conversion of five different feedstock types for biofuels/bioenergy and bio-based products. The following list gives an overview of the case studies. Further information about the case studies can be found in Chaps. 8–14 of this book.

- Argentina (soybean oil, biodiesel)
- Indonesia (palm oil, biodiesel)
- Tanzania (*Jatropha* oil, biodiesel)
- Mali (*Jatropha* oil, biodiesel)
- Costa Rica (sugar cane, bioethanol)
- Brazil (sugar cane, bioethanol)
- Canada (lignocellulosic biomass, 2nd generation conversion technologies)

For the assessment of environmental impacts associated with the case studies, it was decided to focus on the four environmental impacts mentioned in Sect. 4.2.1. Due to differences regarding the ability to address environmental impacts occurring at different spatial levels, a combination of the two techniques described above was used for the assessment of environmental impacts for the case studies: life cycle assessment (LCA) methodology for greenhouse gas emissions and elements of environmental impact assessment (EIA) for biodiversity, water, and soil. Greenhouse gas (GHG) emissions were quantified by IFEU, whereas the impacts on biodiversity, water, and soil were reported by the project partners in a qualitative manner.

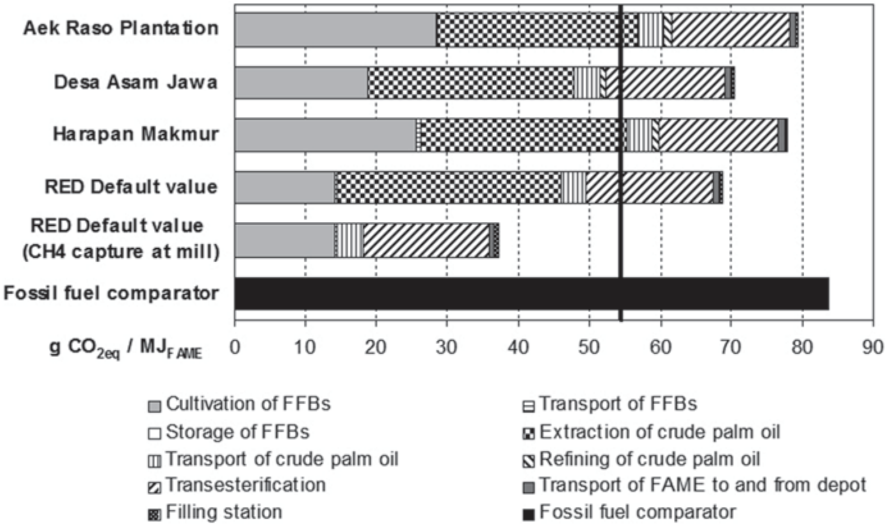

Fig. 4.2 GHG emissions from palm oil biodiesel in Indonesia compared to its fossil fuel comparator. (IFEU based on Wright 2011)

IFEU calculated the GHG balances based on case study-specific data provided by the project partners. The GHG calculations were performed according to the rules laid down in Annex V of the European Renewable Energy Directive (2009/28/EC, RED) (EP and CEC 2009), since the Global-Bio-Pact project was initiated in order to explore whether and how the current list of (environmental) sustainability criteria in the RED can be amended by mandatory socio-economic sustainability criteria. Three tools were used: the BioGrace GHG calculation tool (for sugar cane ethanol, soybean oil biodiesel, palm oil biodiesel) (BioGrace 2011), the ENZO2 Greenhouse gas calculator (for molasses ethanol) (IFEU 2012), and the GEF Biofuel GreenHouse Gas Calculator (for *Jatropha* oil biodiesel) (IFEU 2011).

In the following, the results of only one case study are shown, namely the environmental impacts associated with palm oil biodiesel production in Indonesia. The results for all other case studies can be found in Rettenmaier et al. (2012a).

Example: Palm oil biodiesel from Indonesia Palm oil biodiesel from Indonesia shows negative implications regarding greenhouse gas (GHG) emissions, water resources and quality, biodiversity, and soil. Both feedstock production and conversion contribute to the negative implications (Wright 2011; Chap. 9 of this book).

The most important problem is that palm oil biodiesel production in Indonesia—at least in case of the plantations and mills regarded in the case study—leads to high GHG emissions (Fig. 4.2). None of the investigated three cases reaches the 35 % minimum threshold of the RED (vertical line at 54.47 g CO_2eq / MJ in Fig. 4.2). This is mainly due to, i). the fact that the methane emissions from the palm oil mill effluent (POME) treatment are not captured and ii). the relatively high amount of fertilizers. Only the Desa Asam Jawa case (16 %) is getting somewhat close to the RED default value (for mills without methane capture). This highlights the great potential for process optimization in the palm oil industry, not only in terms of methane capture at the palm oil mill but also in terms of increased use of oil palm biomass residues.

In terms of biodiversity, it was found that all three cases lie within or next to areas of high biodiversity and high soil carbon stocks (Wright 2011). The increasing demand for palm oil is a threat to these neighboring areas, which could be converted to agricultural land, too. If rainforests are cleared and/or peatland is drained, there is a risk that high conservation value (HCV) areas are permanently lost, GHG emissions increased, and soil fertility decreased. 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. POME discharge into nearby water bodies creates another problem which 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 crude palm oil (CPO). Therefore, the negative impacts of the palm oil mill can also affect surrounding rainforests or other areas of high conservation value.

4.3 Linkage Between Socio-Economic and Environmental Impacts

4.3.1 Methodology

The overall aim was to reveal 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, both regarding environmental and socio-economic impacts, the linkages between major environmental and socio-economic impacts of biofuel and bio-based product life cycles are investigated. This is important since positive social impacts are not necessarily associated with positive environmental impacts, and vice versa.

This task was carried out by combining the approach of a SWOT analysis[3] with a classification of various combinations of environmental and socio-economic impacts (see below). First, a SWOT analysis was performed on each Global-Bio-Pact case study which was entirely based on data provided by the respective partners. This way, differences in the biomass production and conversion into the biofuels and bio-based products depending on specific environmental, social, and economic conditions are revealed. The general structure of a SWOT matrix is shown in Table 4.1.

[3] 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. Internal factors are determined by the project/ product itself. All others are external.

Table 4.1 Example of a SWOT matrix: strengths (S) and weaknesses (W) are internal factors (determined by the project/product itself) whereas opportunities (O) and threats (T) are external factors (determined by the outside world)

	Favorable	Unfavorable
Internal factors	Strengths	Weaknesses
External factors	Opportunities	Threats

Table 4.2 Matrix used for the classification of linkages between socio-economic and environmental impacts. Example: A positive correlation results if both environmental and socio-economic impacts are positive

	Positive correlation	Trade-off
Environmental impacts	+	–
Socio-economic impacts	+	+
Environmental impacts	+	–
Socio-economic impacts	–	–
	Trade-off	Negative correlation

Regarding the identification of linkages between socio-economic and environmental impacts the classification depicted in Table 4.2 was applied.

Through the combination of SWOT analyses and classification of the assessed impacts regarding 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.

4.3.2 Results

This chapter presents the results of the analysis of linkages. First, the results of a single SWOT analysis are shown, taking the Indonesian case study as an example. Subsequently, a summary of results of all SWOT analyses is presented, followed by remarks regarding the limitations of the analysis. The SWOT analysis results for all other case studies can be found in Rettenmaier et al. (2012a).

Example: Palm oil biodiesel from Indonesia All information regarding environmental and socio-economic impacts used for this SWOT analysis was entirely obtained from the Indonesian case study performed within the Global-Bio-Pact project, but condensed and interpreted by IFEU and Imperial College. For in-depth insights and a more comprehensive picture on the situation in Indonesia, the reader is referred to the original case study report (Wright 2011; Chap. 9).

Environmental impacts Table 4.3 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.

The weaknesses observed affect all assessed environmental aspects, namely GHG emissions, water resources and quality, biodiversity, and soil. Both the feedstock production and the conversion have negative impacts on the environment. The

Table 4.3 SWOT matrix for the environmental impacts of the production of palm oil and biodiesel in Indonesia (IFEU and IC based on Wright 2011)

S n/a	*W* greenhouse gas emission savings of less than 35 % (5 %–16 %) compared to the fossil reference fuel *W* all three case studies lie next to or within regions of high biodiversity and high soil carbon stocks respectively *W* incidences of water contamination by POME and agrochemicals were reported *W* decline in soil's organic matter, fertility, and soil moisture and increase in soil compaction were reported
O n/a	*T* potential of occupation of protected areas and/or regions of high biodiversity and soil carbon stock

POME palm oil mill effluent

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 peatland 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.

Socio-economic impacts Table 4.4 shows the SWOT matrix regarding the socio-economic 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. Regarding economic aspects the case study report revealed both strengths and weaknesses associated with palm oil production. On the one hand, the implementation of palm oil had positive impacts on the employment situation in most villages and improved the general situation of smallholders. This emphasizes the high economic importance of the production of palm oil. However, the influence

Table 4.4 SWOT matrix for the socio-economic impacts of the production of palm oil and biodiesel in Indonesia (IFEU and IC based on Wright 2011)

Feedstock production	*Feedstock production*
S Palm oil has improved overall employment situation in most of the case study villages	*W* Many jobs in initial phase of plantation are temporary and set with day laborers without most of the protections for permanent workers
S Smallholders claim to be better off with palm oil compared to the past	*W* Wages: at the national level, only around minimum wages; at the regional level, significantly below minimum wages (only 80 % of minimum wage)
S Wages of workers and bigger farmers in smallholder case study at the local level were above minimum wage (110 % and about 200 % per ha, respectively)	*W* Problem with child labor (age 9–17)
S At the local level, the state-owned plantation provides security of employment and social insurance for all their workers	*W* Agrochemical use, harvesting accidents, and restriction of rights of association and trade unions at the regional level
S Free health care for all employees of and all plasma smallholders associated with the state-owned plantation at the local level	*W* Weak bargain position and low income of smallholders due to little organization and their dependency on middlemen or farm gate prices
S In general, large plantations often have their own health clinics	*W* Competition between food use of palm oil and use as biofuel
S At the regional level, stable production of rice and slightly increased production of other food in the past 10 years	*W* Transition from net producers to net consumers of food makes people more vulnerable to high food prices
	W Smallholders of one case study region converted rice paddies into more profitable oil palm plantations causing a deficit in regional food production
	W Increasing number of conflicts across Indonesia over land rights and unfulfilled promises
	W In the case study regions, only 5 % of the workers at the plantation and 15 % at the mill are women
	W Female unskilled workers receive lower wages than male ones
	W At the national level, problems for smallholders in remote areas to gain access to money (unmanageable debts), good planting material, and knowledge about management
Conversion process	*Conversion process*
S At the mill associated with the state-owned plantation, unskilled workers' wage is much higher than minimum wage (nearly 340 %)	*W* Only one (state-owned) company for biofuel blending paying low prices to the producers for their biodiesel
S All permanent workers at the mill at the local level are provided with housing, health care, children's education, and other bonuses	
S Free health care for all employees of the mill at the local level	

Table 4.4 (continued)

Feedstock production	*Feedstock production*
O Well-paid feedstock for oil production	*T* Low potential for future employment generation at the regional level
Conversion process	*Conversion process*
O Increasing market	*T* Slower growth of the biofuel sector at the national level than predicted results in less job creation

of 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 in which oil palm plantations were implemented. 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 FFBs. 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 criticized 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 among 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. 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 labor. 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.

Furthermore, 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 (Wright 2011).

The last important issue for the socio-economic aspects of the case studies refers to the land-use competition between food and palm oil production. Most of the aspects were found as clear weaknesses. Only at the regional level strength was identified. In North Sumatra, a stable or even slightly increased production of food crops was observed in the last 10 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 other plantations, 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.

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 polluting affected water bodies. The last aspect is harmful to the environment and to 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 negatively affects the health of workers and people from the surrounding villages, too. In relation to environmental impacts, 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. Furthermore, 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 mainly negative regarding several issues (see above).

4.3.3 Summary of the Results

Through the SWOT analyses on all Global-Bio-Pact case studies (see Rettenmaier et al. 2012a) several linkages between socio-economic and environmental impacts could be identified (see classification in Sect. 4.3.1). In the following chapter, a number of examples are given (non-exhaustive list):

Positive correlation between socio-economic and environmental impacts ('win-win situation')

- The non-intensive cultivation of *Jatropha* in the investigated case study 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 in the case study related to clearing of natural forests 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 (LUC) often lead to a negative correlation. From an environmental point of view, LUC 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 that are 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 an appropriate framework beforehand. Thereby, these impacts might be able to be minimized.

4.3.4 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 predefined environmental and socio-economic aspects. 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 predefined aspects, so the picture given might be incomplete and even biased.

The authors 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 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: i) 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 ii) to establish causality links between observed impacts and the underlying drivers.

Since most of the biomass feedstock (except *Jatropha*) used for biofuels have been cultivated since a long period for other purposes (mainly food/ feed), the difference between a business-as-usual scenario and a nonfood 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 artifact. First, *Jatropha* has just recently been introduced as a potential feedstock for the production of biofuels. Until then, the nonfood 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.

Regarding the environmental impacts of biofuels and bio-based products, 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 bio-based products (instead of petroleum-based fuels and products) saves non-renewable energy resources and helps mitigating climate change[4]. 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[5]. In other words: there are even trade-offs between different environmental impacts, not only between socio-economic and environmental impacts.

4.3.5 Interpretation

Since "the environment" actually means soil- to grow food; water- to drink, wash, and irrigate crops; 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 links environmental and socio-economic aspects. Ecosystem services are the benefits people obtain from ecosystems. These include provisioning, regulating, and cultural services that directly affect people and as well as 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). Figure 4.3 shows the linkages between ecosystem services and human well-being.

Linking environmental and socio-economic impacts as done for the concept of ecosystem services is quite complex. First of all, this is because environmental impacts are a complex issue in themselves. They differ in terms of timescale (persistence), spatial scale (ubiquity), and (ir)reversibility, among others.

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

[5] 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, organizations, and societies have different preferences; therefore different rankings may be the outcome of the same (objectively obtained) scientific results.

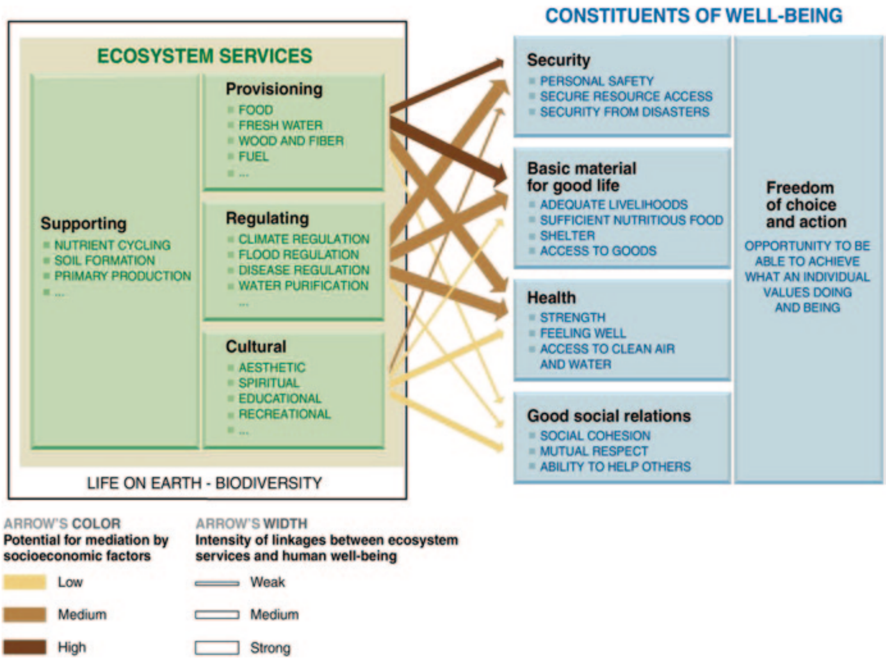

Fig. 4.3 Linkages between ecosystem services and human well-being (Millennium Ecosystem Assessment 2005)

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 timescale, environmental impacts tend to be overlooked by the often shortsighted view of politics and society. Frequently, 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 nonlinear 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 into environmental impacts and the concept of ecosystem services (see above), this means that environmental impacts lead to changes in ecosystem services which in turn negatively affect the constituents of human well-being. Despite 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 non-intensive 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 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 non-intensive 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 true 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’.

4.4 Conclusions

The main areas where environmental and socio-economic indicators are considered to be linked within the Global-Bio-Pact project are land use impacts on food security, ecosystem services, biodiversity, water, and soil.

Different approaches can be taken to link environmental and socio-economic issues, principles, criteria, and indicators. One of these approaches is to use the concept of ecosystem services. This concept proves to be very suitable for establishing the linkage between environmental and socio-economic impacts, but is still new in the business and project arena and requires further development. The number of companies that use approaches and standards such as the Corporate Ecosystem Services Review (ESR) or the Equator Principles is still very limited, particularly in the bioenergy sector.

It can be concluded that trade-offs and negative correlations between environmental and socio-economic impacts are a sign of deteriorations of ecosystem 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, e.g. by raising awareness, but it is definitely not the silver bullet to prevent damage from ecosystems. This applies in particular when only a small share of the global production of an agricultural commodity is being certified, e.g. only the share of vegetable oil used for liquid biofuels production (but not the lion's share used for food or other purposes).

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).

Furthermore, it can be concluded that the impacts associated with the production of a feedstock are fairly independent of its use, i.e. whether the feedstock is used for biofuels and bio-based products 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 biofuel production as such. Therefore it is important to apply the same rules for all agricultural products irrespective of their use for food, feed, fiber, or fuel.

The authors would like to emphasize 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 bio-based product cannot be deduced.

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 assess if biofuel production causes food insecurity and in how far biofuel mandates in developed countries and/ or globally rising energy prices contribute to that (see recent FAO (2012) report produced within the "Bioenergy and Food Security Criteria and Indicators" (BEFSCI) project).

In terms of harmonization of environmental and socio-economic sustainability criteria (Rettenmaier et al. 2012b), our analysis has shown that any strategy should especially focus on the mandates with sustainability requirements such as the European Renewable Energy Directive (2009/28/EC, RED), since these are to a large extent setting the scene. At European level, we therefore recommend to amend the RED by setting new mandatory environmental sustainability criteria regarding soil, water, and air protection, i.e. criteria that have a strong link to ecosystem services (e.g. UNEP et al. (2011)). This way, many social impacts affecting 'security', 'basic material for good life' and 'health' could be covered indirectly. Some of the voluntary certification systems do include such criteria, but since they are not needed to fulfill the requirements of the RED (so far, only criteria related to GHG emissions and biodiversity are mandatory), there is a risk that economic operators opt for the weakest (recognized) certification system which doesn't include the suggested criteria regarding soil, water, and air protection.

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