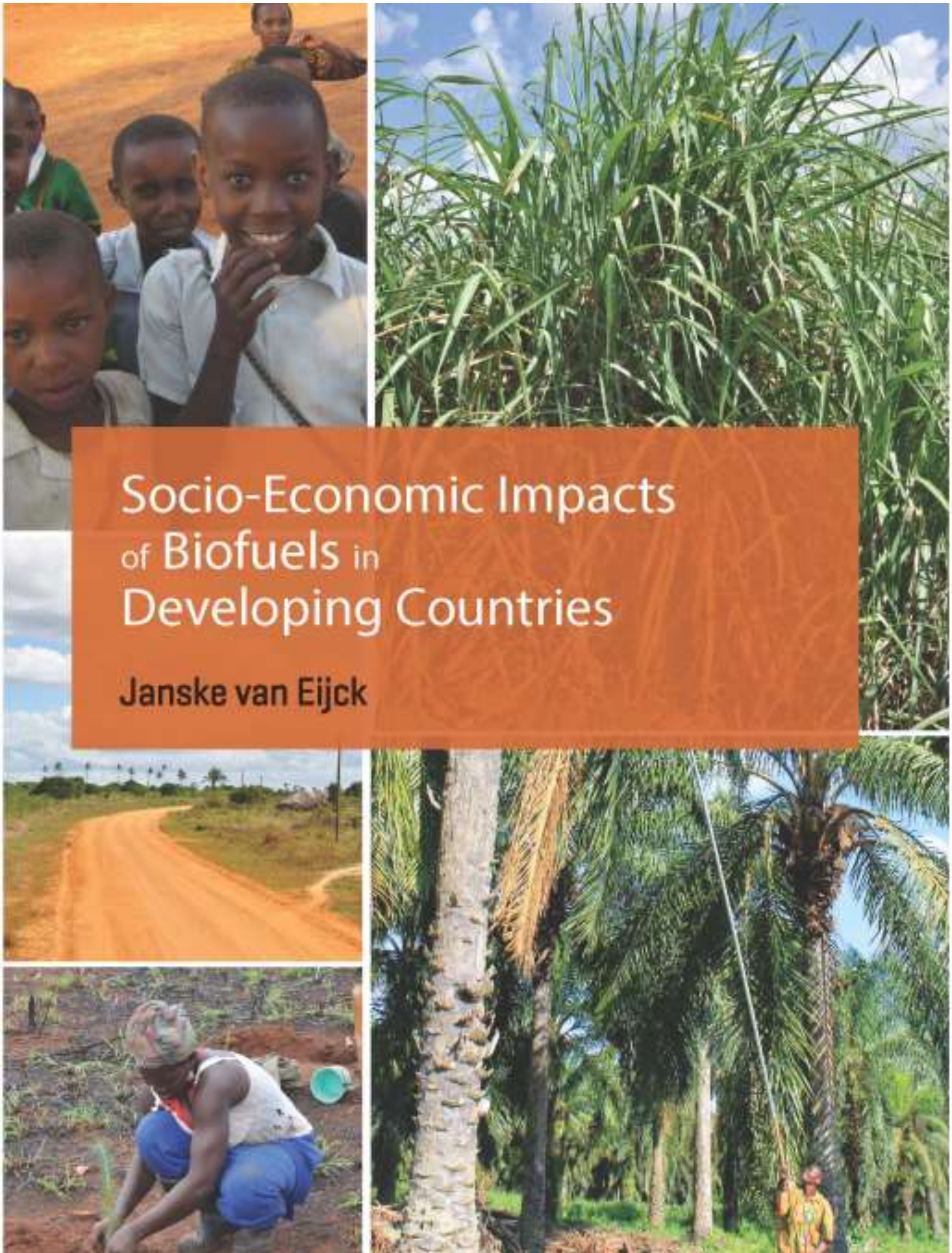
Socio-Economic Impacts
of Biofuels in
Developing Countries
Janske van Eijck

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Janske van Eijck

Copernicus Institute of Sustainable Development, Utrecht University, Utrecht, the Netherlands

April 2014

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Janske van Eijck, April 2014

ISBN: 9789088918520
Cover design: Mark Kamau
Printing: Proefschriftmaken.nl, Uitgeverij BOXpress
Published by: Uitgeverij BOXpress, ‘s-Hertogenbosch

Socio-economic impacts of biofuels in developing countries

Sociaal-economische effecten van biobrandstoffen in ontwikkelingslanden

(met een samenvatting in het Nederlands)

Athari za kijamii na kiuchumi ya nishati ya mimea katika nchi zinazoendelea

(kwa muhtasari katika Kiswahili)

Proefschrift

ter verkrijging van de graad van doctor aan de Universiteit Utrecht
op gezag van de rector magnificus, prof.dr. G.J. van der Zwaan,
ingevolge het besluit van het college voor promoties
in het openbaar te verdedigen op
vrijdag 11 april 2014 des middags te 4.15 uur

door

Janske Adriana Johanna van Eijck
geboren op 19 juli 1980 te Tilburg

Promotor: Prof. dr. A.P.C. Faaij

Co-promotor: Dr. H.A. Romijn

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BaU	Business as Usual
C	Carbon
CGE	Computable General Equilibrium
CO_2	Carbon dioxide
CO_2-eq.	Carbon dioxide equivalent
EC	European Commission
EJ	Exajoule ($1*10^{18}$ joule)
FAME	Fatty Acid Methyl Ester
FAO	Food and Agriculture Organisation of the United Nations
FOB	Free on Board
FT	Fischer-Tropsch
FTE	Full Time Equivalent
GDP	Gross Domestic Product
GEF	Global Environment Facility
GHG	Greenhouse gas
GIS	Geographic Information System
GJ	Gigajoule ($1*10^9$ joule)
h	hour
ha	hectare (10,000 m^2)
IO	Input-output
IPCC	Intergovernmental Panel on Climate Change
IRR	Internal Rate of Return
ISO	International Organisation for Standardisation
Km	kilometre
kWh	kilowatt-hour
m	metre
M€	million Euro
l	litre
MJ	Megajoule ($1*10^6$ joule)
NGO	Non-governmental organisation
No.	Number
NPV	Net Present Value
POME	Palm Oil Mill Effluent
RED	Renewable Energy Directive
SOC	Soil organic carbon
SRC	Short rotation coppice
TZA	United Republic of Tanzania
UNEP	United Nations Environment Programme
UNIDO	United nations Industrial Development Organization
US	United States of America
VAT	Value Added Tax
yr	year

1 Introduction

1.1 Bioenergy and its contribution to a more sustainable energy system

The global demand for energy, and associated services, is increasing. Energy and energy services (lighting, cooking etc.) are required by societies to foster social and economic development, to improve human welfare and health and to serve productive processes (IPCC 2012). Fossil fuels dominate the current energy supply and this leads to a rapid growth in global greenhouse gas (GHG) emissions. The consumption of fossil fuels accounts for the majority of these GHG emissions (IPCC 2012). Climate change is at the top of the political agenda and negotiations are ongoing in order to set an international policy framework for a post-Kyoto era, in which developing countries are expected to commit towards climate change mitigation goals and measures, alongside developed countries.

There are multiple options for lowering GHG emissions such as energy conservation and promoting efficiency, using renewable energy or deploying nuclear energy (IPCC 2012). There are various possibilities to generate renewable energy via solar, wind, geothermal or biomass resources. The advantage of biomass is that the production of biomass for energy generation can contribute not only to climate change mitigation and energy security, but also to rural development and employment generation (Faaij and Domac 2006). Besides these environmental and social advantages, increasing energy prices, particularly of oil, are also stimulating the market for alternative energy sources. Several studies have indicated that the production of crops for energy production has the (technical) potential to contribute up to one-third of the global energy supply in the year 2050 (Smeets et al. 2007; Van Vuuren et al. 2009; Dornburg et al. 2010). Estimates vary widely with respect to the technical potential (due to the inclusion of various restrictions on resource limitations and environmental concerns), but most studies agree that the technical potential of generation of energy derived from biomass (i.e., bioenergy) including crops, residues and organic wastes, in 2050 can reach up to 500 EJ/yr (Smeets et al. 2007; Batidzirai et al. 2012a). Out of the total technical bioenergy potential, dedicated bioenergy crops have the largest (technical) potential of up to 200 EJ/year in 2050 (IPCC 2014).

Besides the advantages of biofuels for climate change mitigation, energy security and rural development, biofuels can also have positive impacts on (regional) GDP, and on mitigation of local pollutant emissions (Chum et al. 2011). Furthermore, bioenergy is versatile because it can be deployed as solid, liquid and gaseous fuels for a wide range of uses, including transportation, heating, electricity production, and cooking (Chum et al. 2011). The main reasons for the deployment of biofuels are:

1. Contribution to energy security through diversification of sources, increasing the number of producing countries and potential to develop 'homegrown' energy;
2. Potential to contribute to necessary GHG emission reductions by replacing fossil fuels;
3. Potential to contribute to development, with special focus on rural development, regeneration of rural areas and improving access to modern energy services.

Many developing countries have a large potential for supplying bioenergy feedstocks (van der Hilst et al. 2011; Wicke et al. 2011; Batidzirai et al. 2012a). Bioenergy production appears to have more scope for developing into an economically competitive supply source in developing countries compared to economically advanced countries, due to often more suitable climate conditions and relatively lower land and labour costs, and the prevalence of low-intensity agricultural management systems in which there is still ample scope for realising high yield improvements through intensification (Smeets et al. 2007; Hoogwijk et al. 2009; Wicke et al. 2011).

Bioenergy production and trade in developing countries can be economically beneficial, e.g. by raising and diversifying farm income and by increasing rural employment. Other benefits are a general improvement of the local livelihood, supporting local services, an improvement in agricultural techniques and local food security, increased access to energy and an improvement of working conditions (Ewing and Msangi 2009; Wicke et al. 2009; Arndt et al. 2011; van der Horst and Vermeylen 2011; Walter et al. 2011; Diaz-Chavez et al. 2013). Furthermore, increased market opportunities can arise and capacity building can be promoted. These positive impacts take place on different scales, from local to regional and beyond. There are millions of smallholder farmers who could benefit from additional income from energy crops.

However, the production and use of bioenergy does not necessarily contribute to sustainable development. Negative impacts occur in developing countries where existing laws for regulating land, water and other resource use are inadequate or not sufficiently enforced, and where the combination of formal and customary rights creates complex situations (German et al. 2011a). The main risks of crop-based bioenergy cultivation for sustainable development and livelihoods, include environmental problems such as deforestation and loss of biodiversity, but also competition for arable land and related resources and consequent social impacts on food security, tenure arrangements, displacement of communities and economic activities, deforestation, impacts on, and unequal distribution of costs and benefits (Sala et al. 2000; Mitchell 2008b; World Bank 2010b; German et al. 2011a; Diaz-Chavez et al. 2013; Hodbod and Tomei 2013; IPCC 2014). But also economic unsustainability can be a cause of negative impacts, for instance when projects are forced to close down. Some crops can only be produced in an economically competitive manner in specific circumstances such as on a certain soil type, in a particular climate condition, or with a specific management level (Van der Hilst et al. 2010; Wicke et al. 2011; Wicke et al. 2013).

A bioenergy system includes various production systems, business models, conversion technologies, capital intensities. These systems can thus cause both positive and negative effects and their deployment needs to be in balance with a range of environmental, social and economic objectives. Co-benefits and risks do not necessarily overlap, neither geographically nor socially (Dauvergne and Neville 2010; Wilkinson and Herrera 2010; van der Horst and Vermeylen 2011). This means that multiple sustainability issues across multiple spatial scales and across development and deployment time scales have to be addressed, and a correspondingly diverse array of sustainability assessment criteria and methodologies are needed in order to enable adequate bioenergy investment decision-making and monitoring of projects during implementation (van Dam et al. 2010b). What makes this particularly complex is that interactions between different types of impacts can reinforce certain effects (positively or negatively) or fully negate each other’s impact. Much is still unclear about the exact circumstances under which bioenergy cultivation and processing are likely to produce beneficial results, and under which circumstances they are likely to induce harms, and about the pivotal factors that drive these diverse outcomes in specific situations. In Table 1-1 an overview is provided of potential positive and negative impacts at different scales.

Table 1-1: Potential positive(+) and negative (-) socio-economic (incl. institutional and technical) and environmental impacts associated with bioenergy options at different scales (adapted from (IPCC 2014))

Impact		Scale
Increase in economic activity, income generation and income diversification	+	Local
Investments in agricultural production systems can lead to overall agricultural management improvements	+	Local
Promotion of capacity building and new skills	+	Local
Efficient biomass technologies for cooking can improve health conditions (mainly for women and children)	+	Local
New job opportunities, bioenergy for local power generation using participaroty technology development can increase acceptance and appropriation	+	Local
Lower environmental impacts and more efficient land use compared to reference agricultural and energy systems	+	local to regional
Contribution to energy independence	+	local to national
Employment creation	+	local to national
Promotion of participative mechanisms for small scale producers	+	local to national
Improvement of soil and biodiversity and abatement of erosion	+	local to global
Promotion of technology development and/or facilitation of technology transfer	+	local to global
Decrease in food security (due to competition with food production; decreased food availability, food access, food usage and food supply stability	-	local to global
Increase in deforestation and/or forest degradation	-	local to global
Displacement of activities or other land uses	-	Local to global
Possible promotion of concentration in income and/or increase in poverty (if sustainability criteria and strong governance are not in place)	-	local to regional
Uncertainty about mid- and long term revenues	-	national
Possible reduction in labour demand due to technology	-	local
Improvement or deterioration in land tenure and land use rights	+/-	local
Cross sectoral spillovers or conflicts between forestry, agriculture, energy and/or mining	+/-	local to national
Impacts on labour rights along the value chain	+/-	local to national
Decrease or increase in conflicts or social tensions	+/-	local to national
Use of local knowledge in production and treatment of bioenergy crops, or discouragement of local knowledge and practises	+/-	local
Empowerment of local farmers by creating local income opportunities, or displacement of smallholders	+/-	local
Positive or negative gender impacts	+/-	local to national
Maintenance or improvement of soil structure, or negative impact on soil quality, water quality and biodiversity	+/-	local to global
Increase or decrease in market opportunities	+/-	local to global
Contribution to t changes in prices of feedstock	+/-	local to global
Improvement e in infrastructure coverage or (if only available for a few social groups), or increase in marginalisation	+/-	local

There has been a substantial increase in global trade of biomass since the start of the 21st century (Walter et al. 2008; Lamers et al. 2014). This is mainly driven by the economic margin between the cost of supply, including feedstock production and supply logistics and the market price in importing countries and by an increased demand due to biofuel promoting policies in Europe and the USA. An international market has appeared and global solid biomass trade for example, has increased more than fivefold in the last decade to 300 PJ in 2010 (Lamers et al. 2012). Hence, due to the sheer growth in production and trade volumes, socio-economic and environmental sustainability issues surrounding production and processing of biofuels have been steadily growing in importance. A range ofinitiatives have been set up that target the development of methodologies and tools to support improved governance of bioenergy value chains, thus ensuring greater sustainability of biofuels. One option to ensure the sustainable production and trade of biofuels is the application of certification systems (Diaz-Chavez 2010). There is globally an increased focus on the development of such sustainability certification schemes and sustainability initiatives (van Dam et al. 2008b; van Dam et al. 2010b; Vissers et al. 2011). Examples of these schemes and initiatives are roundtables of sustainable production (e.g Roundtable of Responsible Soy (RTRS), Roundtable of Sustainable Palm oil (RSPO), the Better Sugarcane Initiative (BSI), and the Roundtable of Sustainable Biofuel Production (RSB)), the Renewable Energy Directive (RED) commissioned by the European Commission, and the Global Bioenergy Partnership (GBEP) which is a governmental initiative. Sustainability is also increasingly incorporated in national policy frameworks, such as investor guidelines and a draft policy for sustainable development of biofuels by Tanzania, and an implemented governance framework for sustainable biofuels by Mozambique (MEM 2008; MEM 2012; Republic of Mozambique 2012; Schut et al. 2014). Furthermore, the International Organization for Standardization (ISO) has included environmental management (ISO 14000) and social responsibility (ISO 26000) in its standards and is now also working on an international ISO biofuel standard.

Sustainability certification schemes and initiatives are developed to assure the sustainability of production systems in different sectors, but for socio economic impacts of biofuels they are not yet fully operational, although certified bioenergy production is required by e.g. the EU Renewable Energy Directive (2009/28/EC 2009). Furthermore, it appears that most of the sustainability certification schemes for biofuels mainly focus on environmental principles, even though there are also serious concerns about socio-economic impacts of bioenergy production activities (van Dam et al. 2010b; German and Schoneveld 2012). The lack of studies that include empirically examined (positive or negative) social impacts at the local level is also acknowledged by Hodbod and Tomei (2013), and by van Dam et al. (2010b), who indicated that certification should be combined with additional impact measurements and methodological tools on a regional, national and international level.

Another obstacle to ensuring the sustainability of biofuels is that data requirements are often found to exceed the resources and capabilities for reliable data collection in many developing countries from which biofuels are sourced (van Dam et al. 2010b). Obtaining good quality field data is difficult due to cultural, infrastructural and other barriers. In addition, some certification schemes are designed primarily with western conditions in mind, which deviate substantially from conditions in the rural areas of many developing countries, e.g. with respect to farming systems, farm sizes, and land use and ownership laws (Romijn et al. 2013). The lack of reliable data is problematic because certification systems cannot function effectively and efficiently without them (van Dam et al. 2010b).

In the next section the current state of the art knowledge on these issues will be detailed, and the major areas in which further progress is still badly needed will be outlined. This is the basis for the formulation of the research aims and questions of this thesis in section 1.3.

1.2 State of the art and knowledge gaps

1.2.1 Determinants of socio-economic impacts of bioenergy projects

The consequences of bioenergy implementation depend on the technology used, on the location, scales and pace of implementation, and on the business models and practices that are adopted, including how these integrate with or displace the existing land use (Chum et al. 2011). The specific location has a large impact because this sets the natural conditions (climate, soil), as well as the socio-economic setting such as employment, poverty and governance (van der Hilst et al. 2011). Furthermore the energy crop production system that is adopted has a large impact. Besides the crop type that is used, this also entails the agricultural management system that can encompass for example a certain level of inputs, a mechanized or manual harvesting method and the (non) use of tillage (Dornburg et al. 2010; Chum et al. 2011). The biofuel supply chains are also highly diverse and are likely to become even more diverse as new technologies for feedstock supply, conversion and use come onto the market (Woods and Diaz-Chavez 2007).

There is a particular lack of studies assessing project sustainability in terms of socio-economic impacts comprehensively (Hodbod and Tomei 2013). Comparisons between different crops, especially for smallholders in developing countries, but also between different business models, are scarce. The few studies that have been done suggest major impact differences between for example plantations and smallholder systems (ProForest Ltd. 2008; Achten et al. 2010; Brittaine and Lutaladio 2010), which signals the importance of conducting further research on these issues. In particular, the viability of energy crops for farmers in a smallholder setting has received limited attention; hardly any field data is available and the risks and opportunities for smallholders remain unclear (Bindraban et al. 2009; Wiggins et al. 2011). Only a few studies, all focused on Mozambique, have reviewed impacts by large plantations (Mota 2009; Peters 2009; Spöttle et al. 2011), but these studies are not comparable to studies about smallholder systems, since hardly any smallholder projects are operating there. Broadhurst's Tanzanian study (2011) is a good attempt, but his study lacks an assessment of economic viability. Furthermore, smallholders typically do not count family labour as an opportunity cost, although this is a potentially crucial aspect in the evaluation of the economic benefits.

Another problem encountered in studies that look at economic sustainability, is that they focus on one specific continent (e.g Africa), or on one specific management type (eg. smallholders) (Mulugetta 2009; Wiskerke et al. 2010), while this does not take into account the large variety in sustainable biofuel production options. One cannot generalise from these context-specific results, as production conditions are heterogenous (Walter et al. 2011).

1.2.2 The effect of different geographical scales on socio-economic impacts

Geographical scales apply to different levels; global (or international), national (country level), regional (by administrative borders or ecological conditions) or local (project or company level). Trends and developments on these different geographical levels influence each other and also interact with each other which creates a complex system for analyses (Van Eijck and Romijn 2008; Romijn and

Caniels 2011). Policy-induced market creation and subsidies for biofuel investment for example in western countries became major drivers for expansion of Jatropha activities in tropical countries, including in Tanzania starting form 2005 (Romijn and Caniels 2011).

On a global level, factors that are important for the bioenergy sector are the oil and energy price, an increased environmental awareness and a global interest in improving agriculture, mandatory blending requirements (by the EU and US), financial instruments for subsidies, the view of western developed countries on utilising biofuels to combat climate change and enhance energy security and technological progress (Van Eijck and Romijn 2008; Romijn and Caniels 2011). Furthermore, the global demand for biofuels is a driver for local impacts of bioenergy projects and global commodity market prices affect the profitability of bioenergy projects.

From various reports it can be concluded that the impacts of bioenergy production systems, and their cost-effectiveness vary greatly from country to country and that some practices and technologies are more sustainable than others (Van Dam 2009; Smeets and Faaij 2010; Chum et al. 2011; Wicke 2011; Van der Hilst 2012). On a national level the factors that can influence developments are; the level of development, the degree of industrialization, political stability, and democracy, policymaking and implementation capacity, whether or not specific biofuel policies or investment protection treaties are in place, the level of economic liberalisation, the availability and structure of the workforce, the infrastructure network (including electricity), availability or scarcity of foreign exchange, and the structure of the agricultural sector (whether or not there are smallholders, average farm sizes, facilities for farmers such as micro credit programmes, or well-running extension services) and land sector (transparency, customary rights etc.) (Van Eijck and Romijn 2008; Romijn and Caniels 2011).

But even within one country, regional differences can be large. Consider for example sugarcane-ethanol in the Central-South (CS) versus the North-East (NE) regions of Brazil. While the production in the CS is well developed and continuously improving in terms of efficiency and sustainability, the productivity achieved in the NE is lower due to climate, terrain characteristics and lower technological levels. There is still room for improvement in the production sector of the NE (Centro de Gestão e estudios estratégicos 2008). Well-developed regions attract more investment and hence employment, such as Maputo and Sofala provinces in Mozambique with good infrastructure and access to skilled labour (Schut et al.

2010a). Van Dam et al. (2009b) assessed regional impacts of soy and switchgrass production for la Pampa province in Argentina. They found that the socio-economic (and environmental) impact of the two bioenergy systems were different. Switchgrass production on degraded grassland showed socio-economic and environmental benefits, but that was not the case for soybean production. Soybean production only showed good overall sustainability performance, if it was produced on abandoned cropland. Regions can also be inter-linked but it is hard to quantify the impacts of one region on the economy of another. Regional trends are for example migration of the rural population to urban areas. This can have impacts on local or national scales for example on national unemployment rates but also on local labour shortage.

On a local level the stakeholders are important, cultural traditions and technical skills and or/knowledge gaps (Van Eijck and Romijn 2008). But also the local state of infrastructure, available facilities and health and education services. Impacts on a local scale can influence local communities in developing regions greatly. Projects that increase access to energy can provide a kick-start in rural development (Achten et al. 2010). But at the same time, the macro-economic impacts of these projects may be small. Van Dam et al. (van Dam et al. 2010b), already indicated that multiple spatial scales should be considered, and that indicators on a micro, meso and macro level should be linked. Many linkages between the different scales have remained unclear so far.

Bioenergy systems can be implemented on different (production) scales; on micro/community/small, medium or large scale scale (Asselbergs et al. 2006; Martin et al. 2009). The impacts from projects on these different production scales will obviously be different, and linkages are possible. National bioenergy programmes for example are typically implemented on a large scale, although they can target small scale projects such as in India where they target small scale producers. A bioenergy system that generates electricity for a village is a typical small scale project, but these can be influenced by global trends such as oil prices.

1.2.3 Quantification of socio-economic impacts

More than one hundred social, economic and environmental impact indicators were already identified by Lewandowski and Faaij (2006), and around 67 different sustainability certification initiatives relevant for bioenergy were identified by Van Dam et al. (2010b). Vissers et al. (2011) furthermore compared 18 certification schemes that are suitable for biofuels for energy purposes. The proliferation of indicators and schemes has caused a serious lack of coherence and consensus among the different certification schemes and how they attempt to measure sustainability impacts (Vissers et al. 2011). There is a need for a further harmonization of the various certification schemes and agreement about indicators to come to a more uniform way of certifying bioenergy systems (Janssen and Rutz 2011; van Dam and Junginger 2011). Also, criteria and indicators may sometimes be too general, vague and leave room for different interpretations (Lewandowski and Faaij 2006; Diaz-Chavez et al. 2013). Recently, some certification schemes have been developed that also include socio-economic aspects. But even within socio-economic indicators, more subjective social well-being indicators that for example point out the level happiness or trust, are often not included (van Dam et al. 2010b; Rojas 2011). Therefore, further methodological development focusing on quantification and monitoring of the socio-economic impacts (e.g. social well-being of a community) is required (van Dam et al. 2010b).

There is also a need to develop concrete and verified methodologies, to measure impacts of biofuel production under specific circumstances, such as for a specific region (Smeets et al. 2008). Examples of studies quantifying the macro-economic impacts of bioenergy production are those by Arndt et al. (2009) and Wicke et al. (2009), who respectively use a CGE analysis on Mozambique and an input/output analysis on Argentina, but this was done on a national scale. And there are also global modeling efforts with CGE-models that use global databases such as GTAP (Dandres et al. 2012).

However, the applicability of such methodologies in developing countries, where existing (reliable) data is often lacking, and severe constraints often exist on the gathering of field data, is more difficult than in developed countries. One obstacle is that big plantations are wary to share key financial performance data. To date, many studies also have not used systematic qualitative and quantitative socio-economic impact indicators (Diaz-Chavez et al. 2012).

1.3 Aim and thesis outline

Based on the knowledge gaps identified in existing literature, the main aim of this thesis is to contribute to an improved analysis and measurement of socio-economic impacts of biofuels in developing countries. Under this overarching objective is subsumed an analysis of how these impacts relate to scale, type of biomass, and the contextual setting, and the identification of production systems with the most positive and least negative socio-economic sustainability impacts. Therefore, the following research questions are addressed:

I. What are the most important determinants of the socio-economic impacts of bioenergy systems (production chains) in developing countries?
II. What is the importance of different scales (local, regional, national, global) on these impacts?
III. What methodologies and tools can be developed to measure these socio-economic impacts?

The research questions are addressed in chapter 2 through 7. Table 1-2 presents an overview of the chapters and the research questions addressed in them.

Table 1-2: Overview matrix of the thesis chapters and the research questions addressed in them.

Chapter	**Research questions**		
	I	**II**	**III**
2 The economic performance of Jatropha, cassava and Eucalyptus production systems for energy in an East African smallholder setting	✓	✓[a]	
3 Comparative analysis of key socio-economic and environmental impacts of smallholder and plantation based jatropha biofuel production systems in Tanzania	✓	✓[b]	✓
4 Current and future economic performance of first and second generation biofuels in developing countries	✓	✓[c]	
5 Global experience with jatropha cultivation for bioenergy: an assessment of socioeconomic and environmental aspects	✓	✓[d]	
6 Analysis of socio-economic impacts of sustainable sugarcane-ethanol production by means of inter-regional input-output analysis: demonstrated for Northeast Brazil		✓[e]	✓
7 Identification and analysis of socio economic indicators; illustrated by bioenergy systems in eight case study countries		✓[f]	✓

[a]: Regional and local scale, [b]: Local scale, [c]: Global and regional scale, [d]: Global and local scale, [e]: Regional scale, [f]: Global, regional and local scale

Chapter 2 addresses research questions I and II by compiling the necessary data and by analyzing the economic viability of three existing energy crop production systems that are grown by smallholders and that are feasible in SSA under marginal conditions (from a farmers’s perspective). Specific attention will be given to the opportunity costs of labour.

Chapter 3 addresses research question I, II and III by conducting a detailed comparative assessment of the major socio-economic and environmental (local) impacts caused by two major different jatropha business models, using two projects operating in Tanzania as case studies: a large centralized plantation and a smallholder (hedge) system organized around a central processor. In order to create a comprehensive and yet practically applicable list of sustainability indicators, “seven key areas of concern” are identified that are mentioned by different sustainability certification initiatives. For each of these, qualitative and - as much as possible - quantitative impact indicators will be formulated.

Chapter 4 addresses research question I and II by analyzing the economic performance of biofuels produced in developing countries, taking large variations between crops and countries into account. The variations that are considered are; fuel output, timeframe, feedstock input, geographical scope and the cultivation management system that lead to 74 different settings.

Chapter 5 addresses research question I and II by providing a comprehensive overview of recent literature based on information from ongoing and discontinued jatropha projects around the world, and by analyzing the lessons learned so far to identify knowledge gaps by evaluating and screening against generally agreed socioeconomic and environmental sustainability criteria.

Chapter 6 addresses research question II and III, and aims to demonstrate a methodology (input-output analysis) that quantifies key socio-economic impacts of a new bioenergy activity for a specific region in a country; the production of bioethanol in the North East of Brazil. The particular socio-economic impacts considered are the impact on GDP, imports and employment. An inter-regional approach is employed to be able to study the impacts in different regions. By using a bottom-up approach, scenarios with projections for 2020 have been drawn, that include not only traditional producing areas of the NE but also potential areas in which sugarcane production in the NE can be expanded. IO analysis allows assessing the economic linkages within the different provinces of the NE as well as studying the dependences of the studied region on the other Brazilian regions. Furthermore, it is possible to assess the different regional contributions to the total impact generated on the national economy.

Chapter 7 addresses research question II and III by reviewing and analysing how the impact of bioenergy projects from various feedstocks and in different geographic locations can be measured. This chapter aims to: 1) compile a broad inventory of potential socio-economic impacts and 2) identify current options and indicators to measure those socio-economic impacts. Furthermore, to 3) apply these to case studies covering different countries and feedstocks and 4) select, apply and evaluate indicators. This will lead to 5) a set of indicators that can be used to assess socio-economic sustainability on different levels: national-, regional- and local level (company or project).

Chapter 8 summarizes and evaluates the findings from chapter 2 to 7, provides answers to the research questions and gives recommendations for policy makers, investors, and for further research.

2 The economic performance of jatropha, cassava and Eucalyptus production systems for energy in an East African smallholder setting

JANSKE VAN EIJCK, EDWARD SMEETS and ANDRÉ FAAIJ

GCB Bioenergy (2012) 4, 828-845[1]

Abstract

This study evaluates the potential economic feasibility of three smallholder energy crop production systems (jatropha, cassava and eucalyptus) under typical semi-arid conditions in Eastern Africa. This feasibility is determined by assessing net present values (NPV), internal rates of return (IRR), benefit-cost ratios (BCR) and payback periods (PBP). In addition, the production costs are compared to the costs of reference energy systems, petrol, diesel and pellets. Low and intermediate input systems are considered and specific attention is paid to the opportunity cost of labour, by considering both family labour (no labour costs) and hired labour. The results show that all family labour settings have positive NPVs and high IRR and BCR values. Moreover, cassava has the highest family labour NPV (2900-5800 US$ ha^{-1}) and the shortest PBP, but the required investment costs are high in comparision with the other crops. If hired labour is used, the NPV of eucalyptus is highest (380-1400 $\$ha^{-1}$), and it is also the least sensitive to changes in wages and yields. Jatropha performs best only for the indicator IRR and only with family labour or low labour opportunity costs. The analysis and comparison of bioenergy production costs shows that eucalyptus pellets (2.6-3.1 $\$GJ^{-1}$) are competitive compared with reference pellets at current market prices (5 $\$GJ^{-1}$). Jatropha SVO (19 $\$GJ^{-1}$) and cassava ethanol (19-36 $\$GJ^{-1}$) are only competitive with fossil diesel (21 $\$GJ^{-1}$) and petrol (25 $\$GJ^{-1}$) in a family labour setting. At current values jatropha biodiesel (24-37 $\$GJ^{-1}$) is not competitive. The economic performance is sensitive to variations in crop yields and yield data are highly uncertain. However, this study demonstrates that there is considerable potential for increasing the economic performance by further improvements in yield, harvesting efficiency and conversion efficiency as well as reductions in transport and packaging costs.

[1] This chapter is based on a research project funded by GEF, UNEP/FAO/UNIDO

2.1 Introduction

The production of biomass for energy generation can contribute not only to climate change mitigation and energy security, but also to rural development and employment generation (Faaij and Domac 2006). Several studies have indicated that the production of crops for energy production has the potential to contribute up to one-third of the global energy supply in the year 2050 (Smeets et al. 2007; Van Vuuren et al. 2009; Dornburg et al. 2010). Bioenergy is an interesting option for Sub-Saharan Africa (SSA), because of the widespread poverty in this region and the benefits that bioenergy production offers for development, especially in rural areas, which hold more than 60% of the population (UNCHS 2001). Other reasons to choose bioenergy are poor access to energy and vulnerability to climate change of agricultural production systems and natural vegetation in parts of SSA. Moreover, SSA is frequently mentioned as a region with a large potential for bioenergy production (Marrison and Larson 1996; Hoogwijk et al. 2005; Smeets et al. 2007).

This great technical potential originates partially from the large areas of agricultural land that are currently producing much less than what is agro-ecologically feasible. The low productivity is caused by the traditional, low input farming systems, in which no or low amounts of fertilizers and pesticides are applied, and no or limited use is made of improved crop varieties and agricultural machinery (Mwangi 1996; IAC 2004). Furthermore, large areas of (partially) suitable land in SSA are currently not used for agriculture and not under forest, shrub and herbaceous cover. Moreover, SSA includes vast arid and semiarid areas (Wicke et al. 2011). According to this study, these areas, in eight SSA countries, have a potential of 300 PJ yr^{-1} for cassava ethanol, 600 PJ yr^{-1} for jatropha biodiesel and up to 4000 PJ yr^{-1} for fuel wood. There are billions of smallholder farmers who could benefit from additional income from energy crops. However, the production and use of bioenergy does not necessarily contribute to sustainable development. Its socio-economic and environmental impact depends on several factors, including the natural conditions (climate, soil), the socio-economic setting (employment, poverty, governance) and especially the energy crop production system used (crop type, low vs. intermediate or high input) (Dornburg et al. 2010; Schut et al. 2010a).

Currently, two cultivation systems are receiving much attention, namely large scale plantations and decentralized production by smallholders. Large scale operations are characterized by the use of large areas of land and advanced crop management techniques in combination with hired labour. These large scale energy crop production systems are often associated with negative social and environmental developments. For example, several large scale (mono-culture) initiatives with jatropha were found to have a potentially negative impact on biodiversity, hydrological balance and ecosystem functions compared to smaller scale initiatives (Gordon-Maclean et al. 2008; Achten et al. 2010). Decentralized energy crop production by smallholders in SSA takes place by cultivation on family owned and family operated farms that are typically semi-subsistence and semi-commercial. The energy crop is sold to a company that processes the biomass into intermediate or final energy carriers. Typically, smallholder production systems have lower yields than large scale energy crop production systems. Smallholder production systems have some advantages: the production of energy crops can provide an additional source of income for the smallholders and sometimes the byproducts can also be used, e.g. as energy, food or fodder (Achten et al. 2007; Achten et al. 2010).

Several studies have evaluated the potential and economics of different energy crop production systems in SSA, including jatropha oil and woody crops by Wiskerke et al. (2010) and biodiesel from palm, castor and jatropha by Mulugetta (2009). However, the viability of energy crops for farmers in a smallholder setting has received limited attention; hardly any data is available and the risks and opportunities for smallholders remain unclear (Bindraban et al. 2009; Wiggins et al. 2011). Furthermore, typically, smallholders do not count family labour as an opportunity cost, although this is a potentially crucial aspect in the evaluation of the economic benefits.

Given the limited available data, the objective of this study is to compile the necessary data and to analyze the economic viability of three existing energy crop production systems that are grown by smallholders and that are feasible in SSA under marginal conditions. Specific attention will be given to the opportunity costs of labour. Smallholders are a heterogeneous group, and they use different agricultural practices (Tittonell et al. 2010). To account for this diversity, this study examines low and intermediate input crop production systems. Within SSA, East Africa has been chosen as the focus region and Tanzania as the focus country because a great deal of information has been derived from this region and this country (although data from several sources had to be combined); moreover, the region is relatively homogeneous regarding the organizational structure of smallholders. For specific sites in this region, climate conditions can differ, still, the yield is very often related to management practices and soil fertility (Fermont et al. 2009). Management practices and related yields are compared to identify the conditions under which these crop systems can be profitable. Three energy crops have been selected that are currently being grown in East Africa on semiarid land: jatropha (Jatropha curcas Linnaeus), cassava (Manihot esculenta Crantz) and eucalyptus (Eucalyptus grandis/camaldulensis). The next section explains the methodology and includes an overview of the input data used per crop production system. The results and sensitivity analyses are presented in the Results section, followed by discussion and finally, Conclusions.

2.2 Methods

The feedstock cost analysis includes the production of the feedstock up to the farm gate, i.e. including harvesting and postharvest processing, if necessary. The input data used in the calculations are presented at the end of this section. First, the variables are further explained.

2.2.1 Brief description of the systems

This study includes smallholder production systems in semiarid areas, which are commonly found in East Africa. The typical size of a smallholder plot is 0.5-2.0 ha (Mitchell 2008a). For jatropha, cassava and eucalyptus, the input data have been presented separately. Jatropha and eucalyptus are perennial crops, whereas cassava is an annual crop. For all crops, the same system length has been taken, namely 24 years. For jatropha the seeds are harvested from year 2 to 24, cassava is harvested annually (in the low input system the yields decline), and eucalyptus has three coppices (years 7, 15 and 23) with a total lifetime of 24 years. For both the low and intermediate input systems, minimal mechanized input is assumed. For example, only manual labour and hand tools, typical of smallholders in arid and semiarid regions, have been assumed (Tigere et al. 2006).

2.2.2 Data sources

The input data for this analysis has been derived from scientific literature, reports and field studies. If available, the under-lying assumptions of the field and literature data have been included. Ranges in data are discussed and used as input for the sensitivity analyses. In a few cases, for example the conversion costs for cassava ethanol, no data was found from either East or Sub-Saharan Africa; therefore, relevant data from other countries was used, such as ethanol conversion costs in Thailand or China[2].

2.2.3 Variables

[2] Exchange rates that were used are $- MZM: 25.3, $-TZS: 1100, $-KES: 78.1; all $ are US, indexation is not considered as most data is derived from 2008 and 2009.

In this study, two variables in the crop production system are examined in detail:

1. *The level of input.* The level of input refers to the use of agrochemicals (pesticides, herbicides), fertilizers and other management practices like pruning and weeding. In low input systems no agro-chemicals, synthetic fertilizers or manure are used and no pruning takes place. This system is common practice in smallholder agricultural systems (Loos 2008; Mitchell 2008a; Fermont et al. 2009). In intermediate input systems, limited use is made of agro-chemicals, synthetic fertilizers or manure and weeding and pruning take place. Irrigation is not applied in any of these systems for practical, economic and environmental reasons. The labour requirements are described per crop together with the level of input as well as related yields.
2. *The type of labour.* Two types of labour are considered, family labour and hired labour. In most smallholder communities, family labour is used, which is typically not accounted for (Loos 2008; GTZ 2009b). This study considers the opportunity costs, i.e. the money people could earn if they were working elsewhere. These costs are considered by assuming that the cost of family labour is zero and that hired labour has an opportunity cost of 2 \$ day^{-1}. In reality this may not always be the case since the employment availability in rural areas may also be lower than labour availability. Furthermore, the opportunity cost of family labour does not have to be zero.

2.2.4 Economic analyses

The economics have been analyzed by means of a cost-benefit analysis (CBA), followed by a sensitivity analysis and a comparison of the costs of bioenergy and reference energy carriers.

2.2.4.1 Cost-benefit analysis (CBA)

A CBA will be used to assess the financial feasibility from the investors' point of view. The three crop systems vary in the investment requirement, their total revenue and the time frame of these revenues; therefore, several indicators are required to arrive at a fair and objective comparison between these systems and to draw a comprehensive picture. The following common indicators are used for this purpose:

- Net Present Value (NPV).
- Internal Rate of Return (IRR).
- Benefit-Cost Ratio (BCR).
- Payback Period (PBP).

NPV

The NPV shows the total amount of surplus (profit) or loss that the project is expected to generate over its lifetime. The NPV has frequently been used in the assessment of the viability of bioenergy production, e.g. by Wiskerke et al. (2010) and van der Hilst et al. (2010). A positive NPV indicates a profit: the expected net cash inflows over the total project lifetime are higher than the cost of financing the project. A negative NPV indicates a loss and the break-even point is reached when the NPV is zero. The NPV is calculated using the equation below (1). The input data are presented at the end of this section.

Equation 2-1

$$NPV = \sum_{i=0}^{n} \frac{B_i - C_i}{(1+r)^i}$$

NPV	Net Present Value [$]
B_i	benefits in year i [$]
C_i	cost in year i [$]
r	discount rate [%]
n	lifetime of project [years]

The lifetime of the project (n) is 24 years for every crop; this means 24 rotations for cassava.

IRR

The IRR shows the rate of profitability. The NPV (see Equation 1) is set to zero while the discount rate is the variable. This determines a rate of interest, which can be compared to the cost of capital. An IRR higher than the cost of capital (e.g. the real discount rate) indicates potential profitability and is the equivalent to an NPV > 0. There should be a good margin between the IRR and the cost of capital to allow for unexpected project risks, especially for smallholders (Van Eijck et al. 2010). Due to mathematical rules, it is only possible to calculate an IRR for longer time series that start with a negative cash flow in the first year, therefore, the BCR is used additionally.

BCR

The BCR is the ratio of the sum of all discounted cash inflows and all discounted cash outflows. A BCR lower than 1 implies a loss, while a BCR higher than 1 indicates a profit.

PBP

The PBP refers to the number of years needed to recover the initial project investment. The total discounted investment shows the sum of the discounted costs over the total project lifetime. A sensitivity analysis is carried out in which the impact of wage rate, yield and value of the product (price) are examined using realistic ranges. Furthermore, an analysis is made of the impact of land cost and packing expenses on the NPV. The ranges that are used are discussed at the end of this section. In addition, for jatropha the harvest ratio is varied and for eucalyptus a postharvest activity is added. This is discussed in greater detail in the Results section.

2.2.4.2 Comparison of the costs of bioenergy systems and reference energy systems

The costs of jatropha straight vegetable oil (SVO) and biodiesel, cassava ethanol and eucalyptus pellets are compared to the costs of reference energy systems that the bioenergy systems can substitute. Reference energy systems are diesel and petrol from fossil oil and pellets produced from conventional biomass sources. The cost of feedstock production is calculated using Equation 2, which takes into account the unequal distribution of costs and benefits over time. This method has been demonstrated by e.g. van den Broek et al. (2000a; 2000b) and van der Hilst et al. (2010); it converts physical units (yield) into annuities. This may seem uncommon, but it is legitimate as the yield represents a monetary value. Data on the cost of transport, conversion and distribution are combined with the cost of feedstock production to estimate the total cost. The cost of ethanol, SVO and biodiesel is compared based on the prices at the port in East Africa.

Equation 2-2

$$C = \frac{\sum_{i=1}^{i_t} \left(ecc_i \sum_{y=1}^{n} \frac{f_i(y)}{(1+r)^y} \right)}{yld \sum_{y=1}^{n} \frac{f_{yld}(y)}{(1+r)^y}}$$

C	Cost of biomass [$ kg^{-1} or $ t^{-1} or $ m^{-3}]
i_t	number of cost items with different time pattern
ecc_i	cost of energy crop cost item [$ ha^{-1}]
n	number of years of plantation lifetime [dimensionless]
$f_i(y)$	number of times that cost item i is applied in year y [dimensionless]
r	discount rate [dimensionless]
yld	yield of the energy crop [kg ha^{-1} yr^{-1} or t ha^{-1} yr^{-1} or m^3 ha^{-1} yr^{-1}]
$f_{yld}(y)$	binary number, harvest (1) or not (0) in year y [dimensionless]

2.3 Input data

A detailed discussion of input data is presented for all three bioenergy systems. The cost of land, wages and discount rates are equal for the three crops and are discussed first.

Data on land costs vary from 0.6 to 34 $ ha^{-1} yr^{-1} (Batidzirai et al. 2006; Wiskerke et al. 2010), therefore, an average of 20 $ ha^{-1} yr^{-1} is used for all e crops as default value. Wages for low skilled employees vary per country, e.g. the minimum wage in Mozambique for the agricultural sector is 2.4 $ day^{-1} (Investment Promotion Center 2009), whereas observed agricultural wages are around 1.9 $ day^{-1} in Tanzania and 2 $ day^{-1} in Kenya (Messemaker 2008; GTZ 2009b). As a result, an average wage of 2 $ day^{-1} has been used as default value. Bryceson (1999) indicated that in rural areas salaries are sometimes lower than the minimum wage. Hoogwijk et al. (2009) used a minimum wage of 0.80 $ day^{-1} in East Africa, which is used as the lower limit in the sensitivity analysis. Furthermore, a 100% increase in wages is taken as the upper limit; this makes the range used in the sensitivity analysis 0.80-4.0 $ day^{-1}(see Results section). Hoogwijk et al. (2009) indicated that wages could be as high as 17 \$ day^{-1} in Southern Africa. This is discussed in greater detail in the Discussion section.

In the analysis, the discount rate of Tanzania is used. As a rule, the real discount rate (r) is calculated by taking the long term lending rate in Tanzania in 2008 of 16.4% plus 1 (is 1.16) divided by the 2008 inflation rate of 10.3% in 2008 plus 1 (is 1.10), see Equation 3. This would equal 5.5% (Bank of Tanzania 2010).

Equation 2-3

$$r = \left(\frac{(1+i)}{(1+p)} - 1 \right) \bullet 100\%$$

r= real discount rate [%]
i = nominal interest rate [number]
p= annual inflation rate [number]

However, inflation was much lower in the years before 2008; for example, in 2006 and 2007 it was 7.3% and 7.0%, respectively. Therefore, the average discount factor of the years 2003-2008: 8.7%, 8.5%, 9.0%, 7.6%, 9.1% and 6.4% respectively, has been used, which is 8.2% (Bank of Tanzania 2010).

2.3.1 Jatropha

2.3.1.1 Crop management

Jatropha is a perennial shrub or tree that originates from Latin America, but which has been grown in SSA for centuries (Brittaine and Lutaladio 2010). The plant requires relatively little management and starts to produce seeds in year 2, depending on soil and climate conditions. Full productivity is only realized in year 8 under marginal conditions (Van Eijck and Romijn 2008). Jatropha can be productive for over 30-50 years. However, for the CBA in this study, a lifetime of 24 years is assumed, which is a more reasonable economic project lifetime and also enables a fair comparison with the other crops (Achten et al. 2008; Van Eijck and Romijn 2008; Brittaine and Lutaladio 2010). The labour requirements for jatropha cultivation are presented in Table 2. The main cultivation practices are described in Appendix A.

2.3.1.2 Yield

There is a great variability in jatropha yields (Achten et al. 2008), because of differences in climate and soil characteristics and the crop management system. Systematic yield monitoring for jatropha started only recently, so there are still considerable uncertainties about the long term yields. Jongschaap et al. (2007) (2007) projected a maximum of 7.8 t ha^{-1} yr^{-1} for mature stands with a range of 1.5-7.8 t ha^{-1} yr^{-1} and also mentioned observed yields (often for 1-2 year-old plantations) ranging from 0.6 to 4.0 t ha^{-1} yr^{-1}. Other sources mention an even larger range of 0.5-12 t ha^{-1} yr^{-1} (Francis et al. 2005). Heller (1996) and Tewari (2007) mentioned 2.0-3.0 t ha^{-1} yr^{-1} as a good range for semiarid wastelands. Table 2-1 shows the yields for jatropha used in our calculations. The data for years 1-5 were taken from a field study with 143 observations in Kenya (GTZ 2009b). This study differentiates between fences, intercropping and monoculture. For the low input system, the observed yields for 'fences' are used for years 0-4, since no inputs are assumed. For years 5-7, an estimate has been made for each year with a maximum yield in year 7 and beyond. For the intermediate input system, the average observed yield in years 1-5 of the monoculture crop system mentioned in the study has been taken. Note that it is not known why year 3 shows a lower yield than years 2 and 4. The yield for years 5-7 have been based on our own estimations, using a similar yield increase as in years 0-5. These yields are relatively conservative, average observed yields by Loos (2008) in Tanzania were higher: 0.3, 2.3 and 358.6 kg ha^{-1} yr^{-1} for the first three years, respectively (see also the sensitivity analysis which uses a range of 0.6-5 t ha^{-1} yr^{-1}).

Table 2-1: Yields for jatropha seeds (dry) used in calculations (kg ha^{-1} yr^{-1})

Year	Low input system[a]	Intermediate input system[b]
0	0	0
1	3	6
2	58	136
3	94	101
4	160	685
5	856	1280
6	950	1650
7	1100	1980
8+	1100	1980

[a]: For years 0-5, the observed yield for 'fences' is used (GTZ 2009b), the yield increase for the years 5-7 is based on an S-curve (yield increase is highest in the middle years) as observed in Mozambique by (de Jongh and Nielsen 2011).

[b]: For years 0-5, the observed yield for 'monoculture' is used (GTZ 2009b), except for year 4 where the observed yield for 'intercrop' is used due to an extremely low yield observation for monoculture (26 kg

ha^{-1}), the yield increase for the years 5-7 is based on an S-curve as observed in Mozambique by (de Jongh and Nielsen 2011).

2.3.1.3 *Labour*

Table 2-2 shows the labour requirement for the two systems. Data on labour requirements for jatropha cultivation have mostly been taken from Loos (2008), who collected data from 131 jatropha smallholders in Tanzania.

Table 2-2: Labour requirements for jatropha for a low and intermediate input system (days ha^{-1} yr^{-1}).

Plantation year→ Task↓	0	1	2	3	4	5	6	7	8-23
Low input system									
Field preparation[a]	32								
Planting[a]	28								
Weed control[b]	31	31	31	16					
Harvesting[c]	0	0	1	2	4	21	24	28	28
Post harvest activities[d]	0	0	0	0	0	2	2	3	3
TOTAL	91	31	32	18	4	23	26	31	31
Intermediate input system									
Field preparation[a]	32								
Planting[a]	28								
Weed control[b]	31	31	31	16					
Pruning[e]	0	11	11	11	11	11	11	11	11
Fertilization[g]	9	6	7	7	7	7	7	7	7
Pest and disease control[h]	7	12	9	9	9	9	9	9	1
Harvesting[c]	0	0	3	3	17	32	41	50	50
Post harvest activities[d]	0	0	0	0	2	3	4	5	5
TOTAL	107	60	62	45	46	62	72	82	74

[a] Loos (2008).
[b] For year 3, half of the number of days of years 0 to 2 as reported by Loos (2008) have been assumed.
[c] 40 kg seeds person^{-1} day^{-1} is assumed (FACT Foundation 2010).
[d] Post harvest activities (dehulling) are assumed to require 10% of the labour demand for harvesting.
[e] Average of days reported by Loos (2008) for years 0 to 3. For year 3 to year 23, it is assumed that the same number of days as in year 3 are needed per year.
[g] Loos (2008) for years 0 to 3. For year 3 to year 23 it is assumed that the same number of days as in year 3 are needed per year.
[h] Loos (2008): for years 4 to 8 the number of days is assumed to be equal to year 3. After year 8 it is assumed that only 10% of this time is required.

These data are in line with the results of Jongschaap et al. (2007) citing (Sharma and Sarraf 2007). They estimated the labour requirement at 70 days ha^{-1} yr^{-1} from year 6 onwards. Francis et al. (2005) mention 200 days^{-1} ha^{-1} for the first year and 50 days ha^{-1} yr^{-1} for the following years.

The harvest efficiency depends on the density of plants and on the yield. Measurements from 12 jatropha crop systems show that the average is 20-30 kg person^{-1} day^{-1} (seeds) for wild jatropha and 50-60 kg person^{-1} day^{-1} (seeds) for well-managed plantations (FACT Foundation 2010). An average of 40 kg person^{-1} day^{-1} is used for both the low and intermediate input systems and this has been varied in the sensitivity analysis (30-50 kg person^{-1} day^{-1}).

2.3.1.4 Land, fertilizers and other input

The price of fertilizers and other types of input are shown in Table 2-3.

Table 2-3: Input and costs required for the cultivation of jatropha (excluding land and labour)

Task	Value	Unit	Number of units per 24 years		Total costs per 24 years ($ ha^{-1})
			Low input system	Intermediate input system	
Field preparation (hoes and machetes)[a]	10	$ ha^{-1}	1	1	10
Planting material (seeds)[b]	1	kg ha^{-1}	1	1	0
Tools for weed control[c]	6	$ ha^{-1} yr^{-1}	4	4	24
Tools for pruning (machetes)[d]	10	$ piece^{-1}	-	3	0-30
Fertiliser (manure)[ef]	11	$ ha^{-1} yr^{-1}	-	24	0-264
Pesticides[f]	20 2	$ ha^{-1} yr^{-1} years 0-8 $ ha^{-1} yr^{-1} years 9-23	- -	9 15	0-210
Packaging material (60 kg bags)	0.45	$ piece^{-1}	322	677	145-305

[a] (GTZ 2009b).
[b] At no cost, Loos (2008).
[c] (GTZ 2009b).
[d] (GTZ 2009b), the lifetime of these tools is assumed to be 10 years.
[e] Average of Loos (2008), 16 $ yr^{-1}, and (GTZ 2009b) 6.3 $ yr^{-1}.
[f] Average of Loos (2008), 15 $ yr^{-1}, and (GTZ 2009b) 26 $ yr^{-1}. After year 8, only 10% of this amount is assumed.

Depending on the year, the total cost of input excluding labour is between 25 and 36 $ ha^{-1} yr^{-1} for the low input system and between 49 and 68 $ ha^{-1} yr^{-1} for the intermediate input system.

2.3.1.5 Value and price of jatropha seed

The prices paid for jatropha seeds in Tanzania in 2007-2009 range from 0.14 to 0.18 $ kg^{-1} (Loos 2008; Mitchell 2008a). In Mozambique, Nielsen & de Jongh (2009) observed 0.09 $ kg^{-1}, whereas in Kenya the study by GTZ (2009b) mentions a range of 0.12-0.18 $ kg^{-1} for the production of SVO. Prices of seeds for the production of soap can be higher, but the market is small (Wiskerke et al. 2010). Prices for seeds for planting were as high as 9 $ kg^{-1} in Kenya, but these values are unrealistically high for mature jatropha seed markets, because this was because of a temporary rush on jatropha planting seeds (GTZ 2009b; Van Eijck 2009). The default value is 0.14 \$ kg^{-1} while in the sensitivity analysis a range of 0.09-0.20 \$ kg^{-1} is used.

2.3.1.6 Production of straight vegetable oil and biodiesel, and a comparison with conventional diesel

Approximately four kg of seeds are needed for the production of one litre of SVO or biodiesel (Achten et al. 2008). Transport, conversion and distribution costs are shown in Table 2-4. More background data is provided in Appendix B.

Table 2-4: Cost of jatropha SVO production and transesterification (excluding feedstock), \$ l^{-1} SVO or biodiesel (based on prices in Tanzania in 2008)

	\$ l^{-1}	\$ GJ^{-1}
Transport seeds to refinery[a]	0.25	7.03
Seedpress conversion to SVO[b]	0.20	5.52
Subtotal SVO processing	0.45	
Transesterification		
Depreciation equipment per litre SVO[c]	0.02	
Cost of electricity consumption[d]	0.001	
Cost of methanol for biodiesel production (200ml added l)[e]	0.19	
Water needed for production[f]	0.01	
Cost of caustic soda for production (4gr per l)[g]	0.01	
Labour[h]	0.05	
Subtotal transesterification	0.28	7.39
Distribution of SVO or biodiesel[i]	0.01	0.19
Total biodiesel processing (excl. feedstock costs)	0.74	20.14

[a] 70% of cost of transport and wholesale dealers margin in Tanzania (Van Eijck 2009)
[b] (Openshaw 2000)
[c] Cost of equipment is 6,450 \$ for a 300 l batch processor, capacity 396,000 l $lifetime^{-1}$ (2 batches per day, 300 days yr^{-1}, lifetime 3 years).
[d] 1.65 kWh $batch^{-1}$, 0.14 \$ kWh^{-1}, 220 l $batch^{-1}$.
[e] Price of methanol: 0.96 \$ l^{-1}, 20 ml l SVO^{-1} required.
[f] Water requirement per batch: 20 l, price: 0.31 \$ m^{-3}.
[g] Price of caustic soda: 0.65 \$ kg^{-1}, 4 gr l SVO^{-1} required.
[h] 4 hr $batch^{-1}$, 1 hour chemical expert (5.10 \$ hr^{-1}) and 3 hours low skilled labour (1.88 \$ hr^{-1}).
[i] Assumed to be similar to distribution of cassava ethanol, (Nguyen et al. 2008).

In 2008, the CIF (Cost Insurance and Freight) price of diesel at the port in Dar es Salaam, our reference system, was 0.80 \$ L^{-1} (Citizen 2008; EWURA 2009). For more information, see Appendix B, Table 2B-12. Based on the CIF price in Dar es Salaam in 2008, minus transport, conversion and distribution, one litre of jatropha SVO could cost 0.34 \$ L^{-1} or 0.09 \$ kg^{-1} seeds, thus remaining at a competitive price, assuming a similar energy content. This is a very low price and is in fact below current market prices for seeds. As the fossil fuel reference price might change in the future, a price of 0.20 \$ kg^{-1} seeds is used as the upper range in the sensitivity analysis. The diesel consumption in Tanzania in 2004 was 650 000 tons (GTZ 2005) and almost 1 M ton in 2010 (EWURA 2010). All in all, this means that there could be a substantial market for SVO.

2.3.2 Cassava

2.3.2.1 Crop cultivation

Cassava (Manihot esculenta Crantz) is an annual bulb shrub that originates from Latin America, but which has been cultivated in Africa for centuries. Cassava is an important food crop in Africa, where 80 Mha are grown in 34 countries (Infonet Biovision, 2009). Cassava is known for its easy management system (FAO and IFAD 2005). It is tolerant to low soil fertility conditions and is drought resistant (Tshiunza 1996; Nguyen et al. 2008; Elbersen and Oyen 2009a). Intercropping with other crops is common (Ayoola & Agboola, 2004). The labour requirements are presented in Table 2-5. The main cultivation characteristics are listed in Appendix A.

2.3.2.2 Yield

The average yield for East Africa in the years 2000-2008 is 8.6 t ha^{-1} yr^{-1}, based on FAOSTAT data (FAOSTAT 2009). There are great differences between different countries; for example, the average for 2008 was 4.3 and 19.1 t ha^{-1} in Zimbabwe and Malawi, respectively (FAOSTAT 2009). Current farmer management practices lead to cassava yields in Kenya and Uganda that range from 6.1 to 11.7 t ha^{-1} yr^{-1} (Fermont et al. 2009). These data are derived from on farm trials (108) and interviews in Kenya and Uganda. A similar range of 5-12 t ha^{-1} yr^{-1} is also mentioned in a study by FAO and IFAD (2005) on traditional cultivation techniques and it also relates well to the average yield in 2007 in Mozambique 7.4 t ha^{-1} (Zvinavashe et al. 2011). For the low input system 6.1 t ha^{-1} yr^{-1} has been used whereas 11.7 t ha^{-1} yr^{-1} has been used for the intermediate input system. Annual cropping systems affect soil erosion more than perennials (such as jatropha and eucalyptus), therefore, in the low input setting a reduction has been included in the yield over time. According to a UNEP report, soil erosion contributes 2-40% to yield reduction in Africa (Nellemann et al. 2009). A conservative 2% yearly reduction of yield from year 4 onwards has been included in the low input setting. In the intermediate input system, the yield level has been maintained throughout the system lifetime of 24 years. With high yielding varieties, yields of 40-60 t ha^{-1} yr^{-1} can be obtained (FAO and IFAD 2005). In addition, Fermont et al. (2009) indicate that yields could increase to 10 t ha^{-1} yr^{-1} with improved agricultural practices, and to 14 and 20 t ha^{-}

^{1} yr^{-1} when improved genotypes and improved fertilizers are used. See also the sensitivity analysis, where a range of 4-20 t ha^{-1} yr^{-1} is considered.

2.3.2.3 Labour

Table 2-5 shows the labour requirements for establishing and cultivating cassava. The data is derived from Tshiunza (1996), who collected detailed data from 2704 cassava fields in six African countries. No data was available for fertilizing, and pest and disease control, the labour demand was assumed to be the same as required for jatropha.

Table 2-5: Annual labour requirements for cassava for a low and intermediate input system (days ha^{-1} yr^{-1})

Plantation year → Task↓	1
Low input system	
Field preparation	30
Planting	29
Weed control	31
Harvesting	52[a]
TOTAL	142
Intermediate input system	
Field preparation	30
Planting	29
Weed control	31
Fertilization	7
Pest and disease control	9
Harvesting	100
TOTAL	206

Source: (Tshiunza 1996) and jatropha data (see Section 2.3.1.3)
[a]: This is the labour requirement for the first year; in the subsequent years the harvest efficiency is 117 kg day^{-1}, so the labour requirements change with the yield levels.

Other data sources compare well with these figures. Literature values range from 173 to 222 days ha^{-1} yr^{-1} (Nweke et al. 2001). However, in Thailand, Nguyen et al. (2008) used a lower labour intensity: 9.3 days ha^{-1} for manual planting and 20-40 days ha^{-1} for manual harvesting.

2.3.2.4 Land, fertilizers and other types of input

The price of fertilizers and other types of input are shown in Table 2-6.

Table 2-6: Annual input and cost required for the cultivation of cassava (excluding land and labour)

Task	Value	Unit	Number of units per year	
			Low input system	Intermediate input system
Field preparation (hoes and machetes)[a]	10	\$ ha^{-1} yr^{-1}	1	1

Planting material (cuttings) [b]	12	$ ha^{-1}	1	1
Tools for weed control [c]	6	$ ha^{-1} yr^{-1}	1	1
Fertilisers (100 kg urea)[d]	52	$ ha^{-1} yr^{-1}	-	1
Pesticides [e]	20	$ ha^{-1} yr^{-1}	-	1

[a] (GTZ 2009b).
[b] Planting material, data from Southwest China, assumed to be 17% of total cost (Zhang et al. 2003).
[c] Taken from jatropha expenses, (GTZ 2009b).
[d] Fertiliser prices are based on FAOSTAT data 2000-2002, urea prices for Tanzania and Kenya.
[e] See jatropha input data, average of (Loos 2008; GTZ 2009b).

Cassava is mostly transported by ox carts, therefore, no packaging expenses have been included (Zvinavashe et al. 2011). The total expense, excluding labour, in the low input system is 75 and 205 $ ha^{-1} in the intermediate input system.

2.3.2.5 Price of cassava

Prices of cassava for ethanol production are not available, because cassava is currently not widely used for the production of ethanol. Instead a default value is used that is based on the price of cassava for food. In Mozambique, the consumer price for fresh cassava in February 2010 ranged from 23 $ t^{-1} fresh (90 $ t^{-1} dry) (Northern Province) to 94 $ t^{-1} fresh (375 $ t^{-1} dry) in Maputo (Agriculture Marketing Information System 2010). Other sources for Mozambique mention prices ranging from 55 to 105 $ t^{-1} (McSween et al. 2006; Econergy International Corporation 2008). Farm gate prices in Malawi were 63 $ t^{-1} (Kambewa and Nyembe 2008), while in Tanzania prices in 2010 were 73-109 $ t^{-1} fresh cassava (Shayo feb. 2010). The average producer price of dried cassava from 2000 to 2007 was 125 $ t^{-1} for seven East-African countries for which data was available; Burundi, Kenya, Malawi, Mozambique, Rwanda, Madagascar, Zimbabwe, Mauritius excluded) (FAOSTAT 2009). Assuming a dry weight percentage of 25%, this is approximately 31 $ t^{-1} fresh. The average price was lowest in 2003, 23 $ t^{-1} fresh or 93 $ t^{-1} dry, and this slowly increased after 2003; in 2007 the average was 46 $ t^{-1} fresh, but with large variations between different countries (e.g. 17 $ t^{-1} fresh in Madagascar and 81 $ t^{-1} fresh in Burundi). Another market is livestock feed (FAO and IFAD 2005), however, no price data are available. The average of the total range in prices (17-94 $ t^{-1}) is 55 $ t^{-1}. Although this is higher than the average from for example FAO, this value was used as default value and the price in the sensitivity analysis was varied. It should be noted that the distance to the market is crucial for farmers who want to sell fresh cassava, as this product cannot be stored for a long time. This means that the prices mentioned are only obtainable by farmers within reasonable distance of the markets. To emphasize the variety in prices, a range of 17-94 $ t^{-1} is used in the sensitivity analysis.

2.3.2.6 Production of cassava ethanol and comparison with conventional petrol

No data was available for cassava ethanol conversion in SSA, therefore, data has been used from Thailand and China (see also the section on Data sources). The efficiency is 133 L t^{-1} fresh cassava (Nguyen et al. 2008). The cost of ethanol production (excluding feedstock) is shown in Table 2-7.

Table 2-7: Cost of cassava ethanol production, excluding feedstock costs

	$ l^{-1}	$ GJ^{-1}[c]
Transport to refinery[a]	0.06	2.9
Conversion[b]	0.25	12.0
Distribution of ethanol[b]	0.01	0.5
Total	**0.32**	**15.4**

[a] Data from Zambia, (Simwambana 2005)
[b] Data derived from pilot plant in Thailand, capacity unknown (Nguyen et al. 2008), 2.5 t fresh cassava produces 1 t cassava chips of which 333 l of ethanol can be obtained. This means 7.5 kg fresh cassava per litre ethanol (133 l t^{-1}).
[c] Energy content 26.4 GJ_{LHV} t^{-1}, density 791 kg m^{-3} (Hamelinck 2004).

CIF price of fossil petrol in Dar es Salaam in 2008 was 0.79 $ L^{-1} or 0.26 $ GJ^{-1} (see Appendix B, Table 2B-14; Citizen, 2008; EWURA, 2009). This means that cassava ethanol could cost 0.36 $ L^{-1} or 48 $ ton^{-1}, excluding transport, conversion and distribution. This falls within the range used in the sensitivity analysis. The petrol market is slightly smaller than the diesel market but still almost 0.5 M ton of petrol was consumed in Tanzania in 2010 (EWURA 2010).

2.3.3 Eucalyptus

2.3.3.1 Crop cultivation

In Africa, eucalyptus is the most widely planted tree genus on plantations, covering 22% of the planted area (FAO 2001 in (Chamshama et al. 2009). Compared with other wood sources, it is one of the fastest growing species (Jagger and Pender 2003). *Eucalyptus grandis* is often planted in Africa, although *Eucalyptus camaldulensis* is often chosen for arid areas (Batidzirai et al. 2006). Eucalyptus can develop a deep root system and is therefore relatively drought resistant (Jagger and Pender 2003). Eucalyptus is cultivated as a short rotation coppice. After a number of rotations the trees are replanted by new ones. Appendix A lists the main cultivation characteristics. In addition, see Table 2-8 for the labour requirements.

2.3.3.2 Yield

Eucalyptus yield depends on climatic conditions such as rainfall. There is a large range in yields mentioned by different sources. For Mozambique the theoretical maximum yield is 35 t dm $ha^{-1} yr^{-1}$ (Batidzirai et al. 2006). By using GIS suitability maps, the maximum yield in Mozambique has been calculated as 22.6 t dm $ha^{-1} yr^{-1}$ with an average of 7.9 t dm $ha^{-1} yr^{-1}$ by Van der Hilst and Faaij (van der Hilst and Faaij 2012). Ugalde and Pérez (2001) collected yields from various countries, 3.6 t dm $ha^{-1} yr^{-1}$ (8.5 $m^3 ha^{-1} yr^{-1}$) in Rwanda, 12.6 t dm $ha^{-1} yr^{-1}$ (30 $m^3 ha^{-1} yr^{-1}$) in South Africa and in Kenya 15.5 to 20.7 t dm $ha^{-1} yr^{-1}$ (30-46 $m^3 ha^{-1} yr^{-1}$). They mentioned that yields higher than 10.5 t dm $ha^{-1} yr^{-1}$ (25 $m^3 ha^{-1} yr^{-1}$) are often achieved but only if conditions and cultivation techniques are good (Eldridge *et al*. 1993 in (Ugalde and Pérez 2001). In Ethiopia, Jagger and Pender (2003) estimated 4.2 t $ha^{-1} yr^{-1}$ (10 $m^3 ha^{-1} yr^{-1}$) on poor sites and 24 t $ha^{-1} yr^{-1}$ (57 $m^3 ha^{-1} yr^{-1}$) on high quality soils. IPCC have mentioned a range of eucalyptus growth (aboveground biomass) of 3 to 7 t dm $ha^{-1} yr^{-1}$, assuming a wood density of 0.42 t m^{-3} (IPCC 2006), and FAO estimates 6.3-23.1 t dm $ha^{-1} yr^{-1}$ (15-55 $m^3 ha^{-1} yr^{-1}$) for eucalyptus (FAO 2001). The total range in literature was 3-24 t dm $ha^{-1} yr^{-1}$ (7-57 $m^3 ha^{-1} yr^{-1}$). An average of the FAO and the IPCC estimates is used, namely 4.7 t dm $ha^{-1} yr^{-1}$ for the low input setting and 15.1 t dm $ha^{-1} yr^{-1}$ for the intermediate input setting (11.7-35.9 $m^3 ha^{-1} yr^{-1}$). In the sensitivity analysis in Section 2.4.2, a range of 3-24 t dm $ha^{-1} yr^{-1}$ is considered (7-57 $m^3 ha^{-1} yr^{-1}$).

2.3.3.3 Labour

Table 2-8 shows the labour requirements for the cultivation of eucalyptus.

Table 2-8: Labour requirements for eucalyptus for a low and intermediate input system (days ha^{-1} yr^{-1})

Plantation year → Cost item ↓	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Low input system																								
Field preparation[a]	15																							
Planting[a]	10																							
Weed control[b]	16	16	16						16	16	16						16	16	16					
Harvesting[a]								37								37								37
TOTAL	**41**	**16**	**16**	**0**	**0**	**0**	**0**	**37**	**16**	**16**	**16**	**0**	**0**	**0**	**0**	**37**	**16**	**16**	**16**	**0**	**0**	**0**	**0**	**37**
Intermediate input system																								
Field preparation[a]	15																							
Planting[a]	10																							
Weed control[b]	16	16	16						16	16	16						16	16	16					
Pruning[c]				11	11	11	11					11	11	11	11					11	11	11	11	
Fertilisation[d]	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
Pest and disease control[e]	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
Harvesting[a]								119								119								119
TOTAL	**56**	**31**	**31**	**26**	**26**	**26**	**26**	**134**	**31**	**31**	**31**	**26**	**26**	**26**	**26**	**134**	**31**	**31**	**31**	**26**	**26**	**26**	**26**	**134**

[a] Data from Tanzania, wood lots with Acacia, survey dates from 1997 in Tanzania, 23 farmers (Ramadhani et al. 2002), post harvest activities such as chopping have not been taken into account. Harvesting compares to 5 min tree^{-1} as mentioned by (Van den Broek et al. 2000b).

[b] Slashing, only years 1-3, Ministry of Natural Resources and Tourism (MNRT) cited in (Wiskerke et al. 2010), after every rotation similar to Van den Broek (2000b).

[c] Pruning (and firebreak maintenance) is required from year 4 onwards (Sayal 2010). An average of 11 days per ha is used, similar to cultivating jatropha (Loos 2008).

[d] Loos 2008, data is average time spent on fertilizing over 3 years of cultivating jatropha.

[e] Batidzirai et al. (2006).

Jagger and Pender (2003) used data from eucalyptus plantations in Ethiopia. They mention labour demands of 251, 81 and 4 days ha^{-1} for community, and 127, 83, 96 days ha^{-1} for privately managed plantations in years 1, 2 and 3, respectively. This is higher than our estimates in years 1 and 2, partially as a result of the higher planting density of 3000-4700 trees ha^{-1} (Jagger and Pender 2003).

2.3.3.4 Land, fertiliser and other types of input

The price and types of input of eucalyptus cultivation are shown in Table 2-9. Packaging of the harvested wood is not required.

Table 2-9: Types of input and cost required for the cultivation of eucalyptus, lifetime 24 years (excluding land and labour)

Task	Value	Unit	Number of units per 24 years		Total costs per 24 years ($ $ ha^{-1}$)
			Low input system	Intermediate input system	
Field preparation (hoes and machetes)[a]	10	$ $ ha^{-1}$	1	1	10
Planting material (seedlings)[b]	0.02	$ $ piece^{-1}$	2500	2500	50
Tools for weed control (hoes)[c]	6	$ $ ha^{-1} yr^{-1}$	9	9	54
Tools for pruning (machetes)[d]	10	$ $ piece^{-1}$	-	3	0-30
Fertiliser (NPK)[e]	30	$ $ ha^{-1} yr^{-1}$	-	24	0-720
Pesticides (liquid)[f]	5	$ $ ha^{-1} yr^{-1}$	-	24	0-120
Harvesting (saw)[g]	3.5	$ $ piece^{-1}$	3	3	11

[a] (GTZ 2009b).
[b] Batidzirai et al. (2006).
[c] Weeding expense taken from jatropha expenses (GTZ 2009b).
[d] (GTZ 2009b), lifetime is 10 years.
[e] Cost of fertiliser for eucalyptus, arid area (Batidzirai et al. 2006).
[f] 1.7 l ha^{-1} at 2.8 $ l^{-1} (Batidzirai et al. 2006).
[g] Van den Broek et al. (2000b).

2.3.3.5 Value and price of eucalyptus wood

Existing applications of eucalyptus in Africa include the production of pulp for paper, timber, poles, fuel wood and charcoal (Batidzirai et al. 2006). The technology to make ethanol from woody biomass is available, although not on a commercial level; therefore, only fuel wood and pellet production have been included. Prices for eucalyptus vary and depend on for example location and availability. Prices for fuel wood are the lowest compared to the other products. A report by the UNEP (2008) mentions that fuel wood prices in developing countries range from 1 to 10 $ m^{-3}. In Mozambique, fuel wood is priced around 0.07 $ kg^{-1}, which is 70 $ t^{-1} or 29 $ m^{-3} (Brouwer and Falcão 2004). In Tanzania, Wiskerke (2010) observed 10.5 $ m^{-3} (25 t^{-1}). In Mozambique, the Ministry of Industry and Commerce defines the reference price of exported wood products. For eucalyptus, prices vary from 15-40 $ m^{-3} (Batidzirai et al. 2006). A conservative average of 10 $ m^{-3} is used as default value. A price range of 1-42 $ m^{-3} is used in the sensitivity analysis (2-100 $ t^{-1}).

2.3.3.6 Production of eucalyptus pellets, and a comparison with other pellets

The average cost of transportation is taken as 24 $ t^{-1} or 1.24 $ GJ^{-1}; this is based on costs in Mozambique (Batidzirai et al. 2006). Conversion (sizing, densification and drying) costs 21 $ t^{-1} or 1.08 $ GJ^{-1} according to Batidzirai (2006), see Appendix B for detailed data. Alternative pellets are priced around 160 $ t^{-1} CIF Rotterdam, which equals 100 $ t^{-1} for East Africa (FOB). This range is included in the sensitivity analysis (GF Energy 2010; Sikkema et al. 2010). The market for pellets has been growing, in 2009 almost 10 million tons of pellets were consumed in the European Union and this figure is expected to grow to 100-300 million tons in 2020 (Sikkema et al. 2011).

2.4 Results

2.4.1 Cost-Benefit Analysis

Table 2-10 displays the NPV, IRR, BCR and PBP of the production of jatropha, cassava and eucalyptus. These values have been calculated for different crop systems and labour types with a discount factor of 8.2% (see Methods section).

Table 2-10: CBA results with chosen default values for jatropha, cassava and eucalyptus

Crop management system	Type of labour	NPV ($ ha^{-1})	IRR (%)	BCR	PBP (yr)	Costs[a] ($ ha^{-1})
Jatropha						
Low	Family	747	41.3	3.4	6	314
Low	Hired	13	8.5	1.0	>20	1050
Intermediate	Family	1304	37.2	3.1	6	614
Intermediate	Hired	-172	5.8	0.9	>20	2090
Cassava						
Low	Family	2897	n/a	6.4	1	538
Low	Hired	-185	n/a	0.9	1[b]	3620
Intermediate	Family	5860	n/a	5.3	1	1350
Intermediate	Hired	1249	n/a	1.2	1	5961
Eucalyptus						
Low	Family	666	30.6	3.1	7	317
Low	Hired	377	16.5	1.6	7	606
Intermediate	Family	2277	40.6	3.9	7	758
Intermediate	Hired	1368	23.3	1.8	7	1634

[a] Discounted costs over the lifetime of the system (24 years).
[b] After 7 years, the NPV becomes negative.

The results show that when the opportunity costs of labour are taken into account (as is the case in the hired labour setting), the NPVs are significantly smaller and even negative for jatropha (intermediate inputs) and cassava (low inputs). Only the NPV of eucalyptus remains positive. If family labour is used, cassava generates the highest returns. Cassava also has the lowest PBP except for low inputs with hired labour, but the BCR shows that there is hardly any profit. Moreover, the investment costs are higher than for the other crops. Therefore, cassava is especially interesting if people cannot wait several years for their returns and if they have enough money and labour to invest. If people do not have a large investment capacity, eucalyptus (family labour) and jatropha (low inputs, family labour) are more feasible options. The investment costs for eucalyptus and jatropha are comparable if family labour is used: Jatropha has slightly higher profits with low input, while eucalyptus has higher profits with intermediate input. If hired labour is used, eucalyptus generates higher profits than jatropha (jatropha is not profitable at all with hired labour and intermediate input). The NPV for jatropha is positive only from year 18 onwards (hired labour), which is much later than eucalyptus (year 7) and cassava (annual returns except with low input and hired labour).

If the input for the production of jatropha production with hired labour is increased from low to intermediate, the NPV will decrease. This indicates that it is not profitable for a farmer to increase input when default values are used. For cassava and eucalyptus it is profitable to increase the level of input of crop production both with family and hired labour, although profits are marginal for cassava. Figure 2-1 shows all the factors used for the NPV calculation.

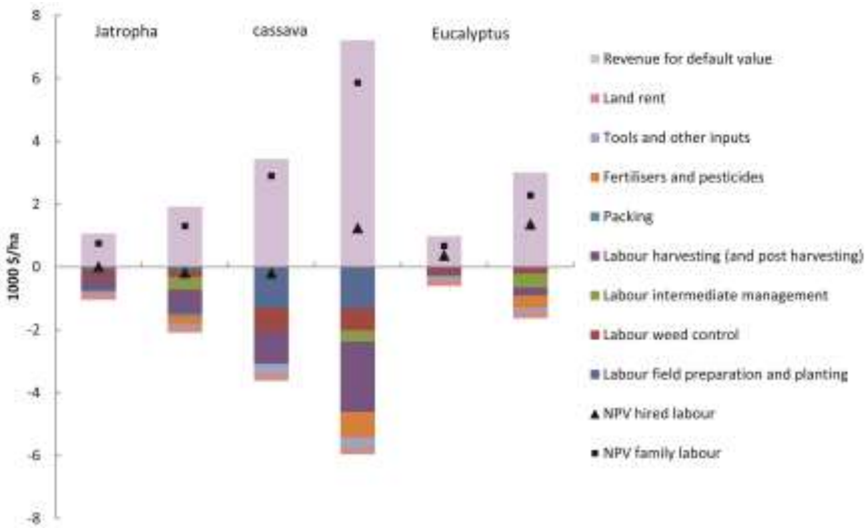


Figure 2-1: NPV contribution per factor for hired labour. Prices based on default values (see Methods section). Values given in 1000 \$ ha^{-1}.

Besides labour, the biggest cost factor for jatropha is land rent. For cassava, in the intermediate input setting fertiliser expenses are relatively high. For eucalyptus, land rent and fertilisers are important cost factors in the low and intermediate input system, respectively.

Labour costs represent 71% of the total expenses for jatropha, 58-73% for cassava and 48-49% for eucalyptus. Harvesting of jatropha and cassava requires the highest amount of labour compared to other tasks. Field preparation and planting requires a relatively high amount of labour for cassava. This is due to the annual cropping system. Some sources suggest a lower labour requirement for the planting of jatropha, but this would hardly affect the NPV as it is only required once in the lifetime of jatropha. The average yearly labour days for jatropha low input system (with a lifetime of 24 years) are 31 days ha^{-1} yr^{-1}, and 72 days ha^{-1} yr^{-1} for the intermediate system. Eucalyptus shows the lowest average labour requirements: 12 days ha^{-1} yr^{-1} and 42 days ha^{-1} yr^{-1} for the low and intermediate input systems, respectively. Cassava is relatively labour-intensive compared to jatropha and eucalyptus, with 142 and 206 days ha^{-1} yr^{-1} for the low and intermediate input systems, respectively.

2.4.2 Sensitivity analysis

The results presented in this study are influenced by a large number of factors, the most important of which have been included here. Figure 2-2 shows the response of the NPV to changes in the variables: wages, yields and prices.

- *Wages.* Wages vary per country, as discussed earlier. A range of 0.8-4.0 \$ day^{-1} is used.
- *Yields.* Section 2.3 discusses the yield ranges included in our analysis. For the low and intermediate input system, the range for jatropha is 0.6-2.0 (low) and 1.5-5.0 t ha^{-1} yr^{-1} (intermediate), for cassava 4.0-10.0 (low) and 6.0-20.0 t ha^{-1} yr^{-1} (intermediate) and for eucalyptus 3.0-10.5 (low) and 10.5-24.0 t ha^{-1} yr^{-1} (intermediate).
- *Prices.* The market prices paid for the crops are varied in line with minimum and maximum prices found in literature and the price at which bioenergy is competitive with the fossil energy alternative (see Methods section). For jatropha seeds, this means 0.09 to 0.20 \$ kg^{-1} (fossil diesel), for cassava roots 17-94 \$ t^{-1} (fossil petrol) and for eucalyptus 1-42 \$ m^{-3} (2-100 \$ t^{-1}) (alternative pellets).
- *Land rent.* Not all smallholders have to pay annual land rent, although it reflects the opportunity cost of land. If these costs are not taken into account, the NPV for jatropha in the low input system would be 294 \$ ha^{-1} (instead of 70 \$ ha^{-1}) and 146 \$ ha^{-1} (instead of -78 \$ ha^{-1}) in the intermediate input setting (both hired labour). This means the production of jatropha would be profitable if land cost is not included. The NPV of

cassava would change to -676 \$ ha^{-1} (instead of -900 \$ ha^{-1}) and 1,094 \$ ha^{-1} (instead of 870 \$ ha^{-1}) for low and intermediate inputs, respectively (hired labour). In addition, the NPV of eucalyptus would change to 597 \$ ha^{-1} (instead of 373 \$ ha^{-1}) and 1,734 \$ ha^{-1} (instead of 511 \$ ha^{-1}) for low and intermediate input, respectively.

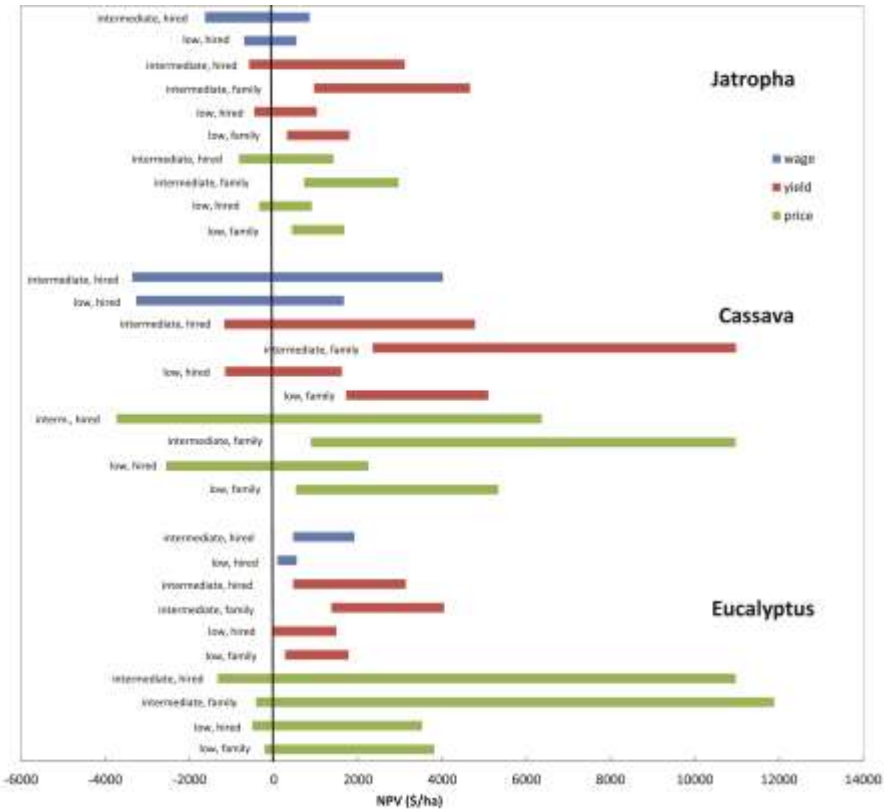


Figure 2-2: Sensitivity analysis for jatropha, cassava and eucalyptus (\$ ha^{-1}). 'Intermediate' and 'low' refer to the input level and 'family' and 'hired' refer to the labour system. See Section 2.3 and 2.4.2 for a description of the values used to vary the wage rate for labour, the yield of the crops and the price that farmers receive for their feedstock.

Changes in yield, prices and wages have a great influence on the NPV. Eucalyptus shows the least sensitivity to changes in the variables. Only when the market price is 1 \$ m^{-3} does the NPV become negative, but this is an exceptionally low price. The break-even price is 5-7 \$ m^{-3}. Cassava shows a high sensitivity towards changes in the variables; the NPV becomes negative in almost all lower limits of the variables, except for yield and prices with family labour. The same is true for jatropha, although the values are slightly less negative in the lower ranges than cassava.

In the calculations for jatropha, it is assumed that one person can harvest 40 kg day^{-1}. If this assumption is altered to 30 kg day^{-1}, the NPV for hired labour becomes -126 \$ ha^{-1} in the low input setting and -424 \$ ha^{-1} in the intermediate input setting. If it is assumed that one person can harvest 50 kg day^{-1}, the NPV for hired labour becomes 96 \$ ha^{-1} in the low input setting and -22 \$ ha^{-1} in the intermediate input setting. Therefore, the harvest rate has a considerable influence, although it is as yet unclear exactly how great this influence is.

No post-harvest activities have been included for eucalyptus. However, if chopping were included, the amount of labour days would increase by 122 days ha^{-1} (which is a relatively high value) in the harvest years (Ramadhani et al. 2002). The influence on family labour is 0; with hired labour the NPV changes from 377 \$ ha^{-1} to 122 \$ ha^{-1} in the low input setting and from 1,368 to 1,113 \$ ha^{-1} in the intermediate input setting.

Cost of packing has been included for jatropha; however, in some cases the wholesaler provides the bags for packing. If the cost for packing is eliminated, the NPV for jatropha becomes 73 \$ ha^{-1} in the low-input, hired labour setting and -68 \$ ha^{-1} in the intermediate-input, hired labour setting. No packing expenses have been included for cassava, but if 50 kg bags were used, the NPV would be reduced to -900 and 70 \$ ha^{-1} in the low and intermediate hired labour setting, respectively. In other words, packing expenses have a great influence on the profitability.

2.4.2.1 Competitiveness with reference energy systems

The feedstock cost of jatropha varies from 0.15-0.61 \$ l^{-1} and the total costs for SVO vary from 0.61-1.07 \$ l^{-1} and for biodiesel from 0.89-1.35 \$ l^{-1} (see Table 2B-13 in the Appendix). Transesterification is not required if jatropha SVO is used as a diesel substitute in modified engines. Government taxes on biofuels have not been taken into account, since there are no such government policies in place in most SSA countries. Note that the cost of transport to refinery could be reduced if more efficient transport systems were in place and the costs of conversion and transesterification might decrease if economies of scale were applied. The total costs per GJ vary from 25-37 \$ GJ^{-1} for jatropha biodiesel and from 19-32 \$$GJ^{-1}$ for jatropha SVO (see Figure 3).

The feedstock cost of cassava ethanol varies from 0.08-0.43 \$ l^{-1} and the total cost from 0.40-0.75 \$ l^{-1} (see Table S2). It is important to note that the cost of conversion can be reduced if economies of scale are applied. Nguyen et al. mention a potential reduction to 0.17 $ l^{-1} instead of 0.25 $ l^{-1} (Nguyen et al. 2008). Figure 2-3 presents a comparison per GJ. Taxes have not been taken into account.

Feedstock cost for eucalyptus varies from 6-15 $ t^{-1} and the total costs range from 51-60 $ t^{-1} (see Table 2B-15 and Figure 2-3 below).

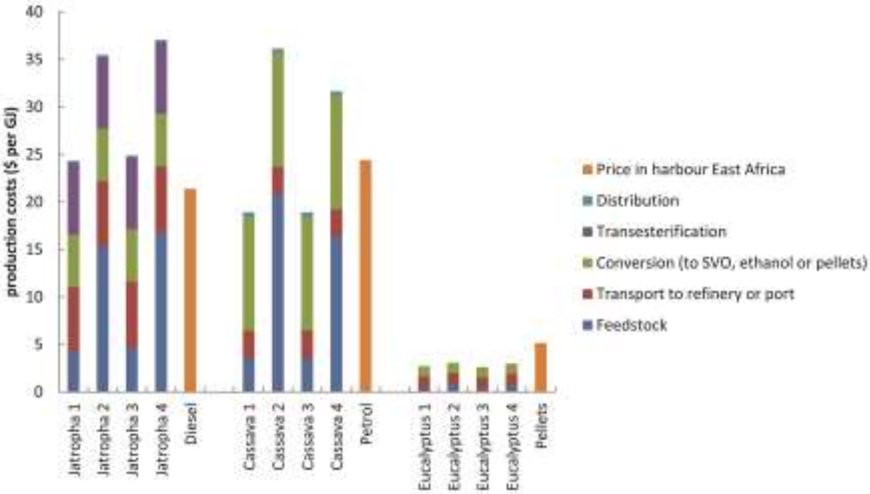


Figure 2-3: Comparison of costs per GJ for jatropha SVO (without esterification) and biodiesel, cassava ethanol and eucalyptus pellets and their alternatives (1=low input system with family labour, 2=low input system with hired labour, 3=intermediate input system with family labour, 4=intermediate input system with hired labour).

From the comparison of the three bioenergy systems and their alternatives, it is clear that eucalyptus has the highest margin between the production costs and the price of alternative pellets on the international market; therefore, of the three crops studied, it is the most competitive. In all systems eucalyptus pellets can compete with reference pellets. With current default values, jatropha biodiesel has higher costs than conventional diesel while jatropha SVO can compete with diesel, but only in a family labour system. Cassava ethanol can compete with petrol in a family labour system but not in a hired labour system.

2.5 Discussion

Land clearing

The amount of labour required for land clearing is dependent on the vegetation of the land and has not been taken into account in this study. Tshuinza (1996) mentions 52 days per hectare for land clearing, compared to 18-166 days ha^{-1} yr^{-1} for the cultivation of the crops. Although land clearing is only required once in the lifetime of the crops and is only of influence when labour is hired, the impact on the NPV can be considerable. The NPV of jatropha would change from 13 to -91 \$ ha^{-1} in a low input setting, and from -172 to -276 \$ ha^{-1} in an intermediate input setting (-60%). For cassava, the NPV would change from -185 to -289 \$ ha^{-1} in a low input setting and from 1250 to 1150 \$ ha^{-1} (-9%) in an intermediate input setting. The NPV of eucalyptus would decrease by 27% in a low input system and by 7% in an intermediate input system.

Prices

Eucalyptus can be highly profitable for smallholders if prices for wood do not decrease to below 5-7 \$ m^{-3}. The minimum price that should be paid to farmers to reach the break-even point for jatropha with intermediate input and hired labour is 0.16 \$ kg^{-1} (the default value is 0.14 \$ kg^{-1}) and for cassava with low input and hired labour the break-even point is at 60 \$ t^{-1} (the default value is 55 \$ t^{-1}). With the default values, the NPV is negative for these settings and therefore the use as additional income is poor, but only slight price increases or the elimination of land costs or packing expenses could mean that farmers can make a profit. A 24-year system lifetime has been chosen; however, jatropha stays productive for a longer period, which will result in a higher NPV. The NPV has been calculated based on current prices; still, these may fluctuate substantially, as observed during the peak in food prices in 2008 (Piesse and Thirtle 2009). The final price of the end product will be partly determined by government taxes, which are not included in our analysis. Currently, it is unclear how high these taxes will be, but if they add up to 35% of the fossil fuel price at the pump, it could lead to a substantial increase in the final price of the bioenergy products. The competitiveness of the liquid fuels (jatropha and cassava) is also determined by the fossil oil price, which fluctuates substantially.

Production costs

The implementation of mechanised cultivation and harvesting systems may reduce the labour requirements and thus reduce the costs. This is especially relevant for jatropha, where harvesting is the most time-consuming task. It will probably take a couple of years before reliable harvesting machines and improved genotypes of jatropha become available. De-hulling equipment for jatropha is already available e.g. in Mali and Honduras at low costs and can increase dehulling efficiency to 100 kg hour^{-1} (de Jongh and Nielsen 2011). The cost of transport may be reduced substantially when more efficient means of transport and infrastructural developments are implemented. A further reduction of the cost of processing, e.g. by increased efficiency of conversion or using by-products, would also increase competitiveness. For example, corn-ethanol conversion costs in the US are 0.14 $ l^{-1} (Hettinga et al. 2009), which is almost half of our default value for cassava ethanol. It is unlikely that such low costs can be achieved in Africa on a short term, although sugarcane ethanol factories are currently being developed in Africa on a commercial scale. No value for by-products has been included, even though the volumes and revenues may be substantial and may reduce the total cost of bioenergy.

Yields

Economic performance is sensitive to the crop yields while yield data are highly uncertain. Improved agricultural practices may lead to higher yields in the future, which will increase competitiveness. For cassava, yields could be much higher than our default value, and this would make cultivation profitable. Improving agricultural practices led to a 100% increase in cassava yield in East Africa, but current yields are still well below what is agro-ecologically attainable (Fermont et al. 2009). On the other hand, an annual 2% yield decrease over time has been assumed for the cassava low input system, but this may be too conservative as soils may deplete. The difference between the yield level over time for annual and perennial systems should be further investigated. The limited economic benefits of current jatropha cultivation with low yields are confirmed by other researchers (GTZ 2009b; Mujeyi 2009). Jatropha breeding programmes have been set up during recent years, and improved plant material will become available on a commercial scale, however this will be in a few years' time (Brittaine and Lutaladio 2010). An increase in input leads to a better performance for eucalyptus and cassava, but to a decreased performance for jatropha. Therefore, at current practices and yields, a crop management system with low inputs is recommended when cultivating jatropha. Research on eucalyptus takes place in for example Brazil (MCT 2008), but the potential for yield increases are difficult to quantify.

Markets

The potential bioenergy markets in Tanzania and Europe are large, and it is expected that the global biofuel market will grow exponentially (Lamers et al.

2011). However, this does not imply that smallholders have access to these markets. This aspect should be analysed further.

Other benefits

Non-financial benefits such as an improvement in the local energy supply security or non-financial disadvantages are excluded. Examples of additional benefits for jatropha are its medicinal use, the prevention of wind erosion and the possibility to generate electricity in a generator (Kumar and Sharma 2008), for cassava the use of processing waste in a biogas digester (Zvinavashe et al. 2011), and for eucalyptus the soil and water erosion control and the potential to regenerate degraded soil (Jagger and Pender 2003). In addition, the eucalyptus and cassava systems also have alternative markets, such as food in the case of cassava (fresh roots or dried chips) and wood products such as timber in the case of eucalyptus; this makes them less risky options for smallholders. Cassava roots can stay in the soil for more than a year and are sometimes used as 'famine-reserve' (Infonet Biovision 2009). These additional and alternative benefits should also be taken into account.

Food security

In Sub-Saharan Africa food security is of great importance. Crop substitution may lead to a reduction of food production in favour of fuel production. Land used for biofuels can also be used for the production of food, and the food crop cassava could potentially be used for biofuels, thus losing its value as a food crop. Food security depends on food availability but also on food accessibility. The latter is influenced by household income level, but also by factors such as market accessibility and infrastructure. The farmers' income is also an important factor. The three crops analysed in this chapter can generate income and thus contribute to increased food security. However, the NPV of these crops can also be negative, and it is unclear whether the market access for these crops is stable. In addition, it is also unclear whether a potential negative trade-off exists between food production and bioenergy cultivation due to a reduction of time available for cultivating food plots. Smallholders have multiple options for their labour investment, such as livestock or other crops; further research taking into account more alternatives may generate better insight into additional possibilities. Furthermore, increased food demand and reduced supply on local markets may result in sustained elevated prices and food deficits. It is unclear to what extent an increase in agricultural knowledge (spillover) and the resulting increased food crop yields can make up for this. Further research is required to determine the net impact on food security of increased biofuel production. A feasibility study with a broader scope should include profitability estimates of common food crops; however this is beyond the scope of the present study. The stability in food supply can be increased by introducing the possibility to shift from using cassava for fuel to using it for food and vice versa, depending on the needs of the local population.

Other regions

It depends on typical factors such as the wage rate and land costs whether the cultivation of these crops are also viable in other areas. Using the opportunity cost of land and labour included in a study by Hoogwijk et al. (2009), a comparison between East Africa and other world regions shows Southern Africa to have higher land and labour costs, Asia to have higher land costs and Latin America to have higher labour costs. This may reduce the viability of the production systems in these regions. However, there are great differences between different countries. For example, wages in the agricultural sector in Mexico in 2004 were around 200 \$ month^{-1} or 9 \$ day^{-1}, whereas in Nicaragua (2004) they were only around 50 \$ month^{-1} or 2 \$ day^{-1} (LABOURSTA). However, doubling the wage rate in the sensitivity analysis indicates that the cultivation of eucalyptus is less sensitive to changes in the wage rate than the other crops. Therefore, even in regions where the wage rate is higher, eucalyptus cultivation may still be profitable for farmers. Besides differences in financial feasibility, local circumstances are also different; for example, the size of an average smallholder plot and land rental arrangements may vary substantially. Therefore, more detailed research on the differences in agricultural institutions, management and economics of systems from a broader perspective is required to analyse the economic viability in other regions.

2.6 Conclusions

The economic analysis shows that the opportunity costs of labour has a major impact on the results. All family labour settings have a positive NPV and much higher IRR and BCR values than hired labour settings. Especially for labour intensive energy crop production, the effects of opportunity costs can be substantial. The analysis shows that in a family labour setting, cassava has the highest NPV (2900-5800 \$ ha^{-1}) and the shortest PBP; however, the required investment costs are higher than for the other crops. With hired labour, the NPV of eucalyptus is highest (380-1,400 \$ ha^{-1}). Eucalyptus is also less sensitive to changes in wages and yields than the other crops and can be highly profitable for smallholders if prices for wood do not decrease to below 5-7 \$ m^{-3}. Jatropha performs best only for the indicators IRR and only with family labour. If wages rise, which is not unlikely considering the relatively high wages in for example South Africa (LABOURSTA), the opportunity costs may become even be higher. However, the opportunity cost of labour is also influenced by the people's opportunities to earn an income in another way; this choice is not always present in rural settings.

The analysis of bioenergy production costs and their comparison to the reference energy systems shows that eucalyptus pellets (2.6-3.1 \$ GJ^{-1}) are competitive compared to reference pellets at current market prices (5 \$ GJ^{-1}). Only in a family labour setting are jatropha SVO (19 \$ GJ^{-1}) and cassava ethanol (19-376 \$ GJ^{-1}) competitive with fossil diesel (21 \$ GJ^{-1}) and petrol (25 \$ GJ^{-1}). Jatropha biodiesel (24-37 \$ GJ^{-1}) is not competitive at current values.

This study has shown that each crop has specific circumstances under which its cultivation is profitable. The economic performance is amongst others, sensitive to variations in crop yields and yield data are highly uncertain. Therefore, promotion of the crops should be based on site-specific conditions. Further research is needed to compile more accurate site-specific data on yields, labour requirements and market conditions to gain more insight into the economic performance and risks of energy crop production systems in semi-arid regions. However, this study demonstrates that there is considerable potential for increasing the economic performance by further improvements in yield, harvesting efficiency, and conversion efficiency as well as reductions in transport and packaging costs.

Acknowledgements

We would like to thank Martijn Rooijakkers of the Eindhoven University of Technology (TU/e), who improved the jatropha data section, Sicco Kolijn, who commented on the cassava data, and the anonymous reviewers who provided valuable comments. This study is part of the GEF UNEP/FAO/UNIDO Targeted Research Project: Global Assessments and Guidelines for Sustainable Liquid Biofuels Production in Developing Countries and is based on work within the COMPETE project, which is co-funded by the European Commission in the 6th Framework Programme.

2.7 Appendices to Chapter 2

2.7.1 Appendix A: Cultivation practices

A-1 Cultivation practices Jatropha

Cultivation practices are described in e.g. Achten et al. (2008), Jongschaap et al. (2007) and by the FACT Foundation (2010). Agricultural machinery is not used by Jatropha smallholders (Tigere et al. 2006; Loos 2008; Mitchell 2008a). The main practises are described below;

- *Field preparation.* Jatropha can survive on soil with a low nutrient availability and in regions with low rainfall, but cannot survive water logged conditions (Achten et al. 2008). Ploughing, marking and pitting are needed to prepare the field for the planting of Jatropha, according to GTZ (Endelevu Energy), based on a field study among circa 300 Jatropha farmers in Kenya (GTZ 2009b).
- *Planting.* Jatropha can be propagated by vegetative (cuttings) or generative (seeds, seedlings) methods. Seeding takes place at the beginning of the rainy season. The planting distance is 2.5 x 2.5 m or 1600 trees ha^{-1}, though smaller or wider spacing and planting in hedgerows, are also possible (Achten et al. 2008). According to Loos (2008), planting is done using seedlings (planting, nursing, transplanting), this is what we assumed in our study. The labour requirements are assumed the same in both input systems.
- *Weed control.* Based on detailed investigations among 74 Jatropha smallholders in North Tanzania, weeding is needed during and after the rainy season during the first 4 years, after that there is no more competition for sunlight (Mitchell 2008a). Weeding is a crucial aspect of Jatropha management, therefore we assume that weeding is applied in both input systems (Loos 2008).
- *Pruning.* Pruning is needed for two reasons. First, Jatropha can grow up to 8 metres if not pruned, which complicates harvesting. Second, Jatropha forms flowers and seeds in clusters at the end of a branch. Pruning increases the number of branches and therefore the number of fruits and yield (Achten et al. 2008). But yield increases only if the branches also receive sunlight (van Peer 2010). Pruning of ⅔ of the branches before the rainy period is advised, as well as pinching the terminal shoot once at 6 months. Periodic thinning is advised for plantations (Jongschaap et al. 2007; Achten et al. 2008; Behera et al. 2010). In this study pruning is only applied in the intermediate input system and is done on an annual basis.
- *Fertilisation.* Fertilisation can increase the yields significantly (Achten et al. 2008). Based on the nutrient composition of Jatropha fruits taken from Jongschaap et al. (2007) harvesting 1 t of seeds removes 14.3-34.3 kg N, 0.7-7.0 kg P and 14.3-31.6 kg K from the soil (Achten et al. 2008). Chemical fertilisers are not commonly

used and are even claimed to have less results than organic manure in degraded soils (GTZ 2009b; Behera et al. 2010). Therefore, in this study, we assumed organic manure as fertiliser in the intermediate input system. An average of 1.2 kg tree^{-1} is applied in Kenya, 1.4 times year^{-1} which results in 2765 kg ha^{-1} yr^{-1} assuming 1600 trees ha^{-1} (GTZ 2009b). This is what we assumed in our study. Depending on the manure composition this would enrich the soil with 10-32 kg ha^{-1} N, 2-28 kg ha^{-1} P and 7-18 kg ha^{-1} K (Tigere et al. 2006; Marino et al. 2008).

- *Pest and disease control.* Jatropha is sensitive to fungal and insect attacks during the first years. In Kenya 46% of the Jatropha farmers reported the occurrence of Golden Beetles that eat young leaves and shoots and 29% reported ‘leaf spotting’ (*Colletotrichum gloeosporioides*), which is caused by fungi or bacteria. Powdery mildew, Red Beetles and fungus also occurred (GTZ 2009b). Some other common pests are; *Scutellera nobilis*, inflorescence and capsule-borer (*Pempelia morosalis)*. Some other reported diseases are; root rot (*Clitocybe tabescens*) and rust (*Phakopsora jatrophicola*) (Tewari 2007). According to Achten et al. (2008) fertilization, irrigation and other crop management activities increases the susceptibility for pests and diseases and therefore only in the intermediate input system pest and disease control is applied, on an annual basis. From year 8 onwards only a fraction (10%) of the inputs are assumed.
- *Harvesting.* Harvesting is done manually in repeated visits during the harvest season, which lasts several months (Mitchell 2008a). The harvest season generally starts 1-2 months after the rainy season. Mechanized harvest systems are being developed, but is problematic, because both ripe and immature seeds are present and flower damage can occur (Jongschaap et al. 2007). One person can harvest around 40 kg seeds day^{-1} on average, although much higher and lower figures were also found (FACT Foundation 2010).
- *Post harvest activities.* Jatropha can be collected as fruits or seeds. When fruits are collected dehulling is required. Drying of the seeds is required if humidity levels are high and packing is needed to store and transport the seeds. Normally maize bags with a capacity of 60 kg are used (Loos 2008; Van Eijck and Romijn 2008).

A-2 Cultivation practices Cassava

- *Planting.* Cassava is planted by vegetative propagation, by planting the stems of mature plants (Tshiunza 1996; Nguyen et al. 2008). 10-20,000 stems ha^{-1} are planted at the beginning of the rainy season (Elbersen and Oyen 2009b) though farmers in East Africa often plant in lower densities (3200-6400 stems ha^{-1}) (Fermont et al. 2009).
- *Weed control.* Weeding is required every 3 to 4 weeks during the first 2 to 3 months, after that the plant can compete for sunlight (FAO and IFAD 2005; Nguyen et al.

2008; Elbersen and Oyen 2009a; Fermont et al. 2009). For both input systems weed control (by using hand tools) is applied, this is very common (FAO and IFAD 2005).

- *Pruning.* Pruning can increase the yield of cassava as mentioned in (Ayoola and Agboola 2004). Pruning is assumed to be applied only in the intermediate input system.
- *Fertilisation.* Fertilisers are an important aspect to increase yields, especially on marginal soils (Fermont et al. 2009). 100 kg ha^{-1} of NPK 15-15-15 seems optimal (Hillocks et al. 2001; Ayoola and Agboola 2004; Fermont et al. 2009). Tshiunza (1996) mentions that the use of fertiliser in a low input system is not common in the 6 African countries he studied. We assumed fertilising only in the intermediate input system.
- *Pest and disease control.* Cassava is susceptible to diseases like the mosaic virus or brown streak, this causes reduced yields (INIA 2003, Tresh 2001 cited in (McSween et al. 2006). Only in the intermediate input system pest and disease control is applied.
- *Harvesting.* Cassava is an annual crop, though it is possible to leave cassava in the soil and harvest after two years (Infonet Biovision 2009).
- Post harvest activities are not included for cassava, because cassava is typically sold fresh by smallholders. Though it then has to be further processed within 2 days. Drying is required when cassava is sold as chips (Elbersen and Oyen 2009a).

A-3 Cultivation practices Eucalyptus

- *Planting.* Eucalyptus is planted from seedlings, depending on the climate and soil fertility the planting density ranges from 2500-4000 trees ha^{-1}(Batidzirai et al. 2006). We assumed a planting density of 2500 trees ha^{-1} for both input systems.
- *Weed control.* In the establishment phase weeding is an important factor to ensure optimal plant growth (Van den Broek et al. 2000b). We assumed that manual weeding is applied during 3 years after every rotation for both input systems (Van den Broek et al. 2000b).
- *Pruning.* Pruning increases the yield since the energy can be directed to the main stem instead of to the branches, it is required after the third year (Sayal 2010). We assumed pruning only in the intermediate input system, this also includes firebreak maintenance.
- *Fertilisation.* Fertilising is an important factor to increase yield (Van den Broek et al. 2000b). Laclau et al. (2003) have studied several sites in Congo to determine the nutrient dynamics for Eucalyptus. They indicated 102 kg ha^{-1} yr^{-1} fertiliser is required, N (64), P (8), K (30), this is the value we used in the intermediate input system.

- *Pest and disease control.* Eucalyptus is susceptible for insects (termites, Eucalyptus snout beetle), pests (locus) and fungi (Jagger and Pender 2003). Pest and disease control is only used in the intermediate input system on an annual basis.
- *Harvesting.* 7-year rotations (coppice) for semi-arid, and 10-year rotation periods for arid regions are common (Batidzirai et al. 2006) citing Macucule, 2001). Rotation periods for poles are longer, >18 years (Sayal 2010). We have assumed an 8 year rotation period with three rotations, so a total lifetime of 24 years. Harvesting is done manually in both the low and intermediate input system.
- *Post harvest activities.* Felled logs can be sold directly for poles. For timber production some processing is required. If it is sold as fuelwood, the harvested logs have to be chopped (Ramadhani et al. 2002). However, if the logs are sold for pellet production they do not have to be chopped at the production site. Therefore we assumed no chopping for both low and intermediate input system.

2.7.2 Appendix B: Input Data

B-1 Input Data Jatropha

Conversion, transport and distribution

While SVO can be used in blends or adapted engines, biodiesel can be used directly. Transesterification is required for the production of biodiesel. 1 litre SVO is converted into 1 l biodiesel at cost of 0.28 $\$ l^{-1}$ biodiesel, based on expenses for the production of Jatropha biodiesel by a relatively low tech unit in Tanzania in 2008, see Table 2B-11. A large share of this cost is due to the high price of methanol in Tanzania. Distribution is included from refinery unit to the port, to be able to make a comparison to conventional diesel. Jatropha biodiesel and conventional diesel have an almost equal energy content; 37.3 MJ l^{-1} and 37.4 MJ l^{-1} respectively (Sahoo and Das 2009). Jatropha SVO has an energy content of 36.2 MJ l^{-1} (Achten et al. 2008).

Table 2B-11: Jatropha SVO and biodiesel costs per litre ($\$ l^{-1}$).

	Low family	Low hired	Intermediate family	Intermediate hired	Diesel
Feedstock	0.15	0.55	0.17	0.61	
Transport to refinery[a]	0.25	0.25	0.25	0.25	
Conversion SVO[a]	0.20	0.20	0.20	0.20	
Transesterification[a]	0.28	0.28	0.28	0.28	
Distribution[a]	0.01	0.01	0.01	0.01	
CIF Dar es Salaam[a]					0.80
TOTAL SVO	0.61	1.01	0.63	1.07	**0.80**
TOTAL biodiesel	**0.89**	**1.29**	**0.91**	**1.35**	

[a] See data input Section for sources

Transport of the seeds from the smallholders to the refinery take up a major part of the expenses, this is due to the large transportation distances, poor quality infrastructure and inefficient transport systems that the (relatively new) Jatropha market currently faces. Small distances, up to 30 km, are covered by bicycles or ox-charts in Tanzania, for larger distances minibuses, landrovers, buses and trucks are used, depending on the volume. In Tanzania the difference between purchasing from smallholders directly (at 100 TZS, 0.09 \$ kg^{-1}) and at the factory gate (at 200 TZS, 0.18 \$ kg^{-1}) comes from transport and margins for wholesale dealers (Van Eijck 2009). We assumed 70% of this amount as transport costs (0.25 \$ l^{-1}). The conversion costs are around 0.20 \$ l^{-1}, based on a motor press in Zimbabwe (Openshaw 2000).

Distribution costs include costs from factory to petrol station, and are similar to cassava ethanol distribution costs.

Comparison with reference systems

Diesel prices in East Africa vary between countries, ranging, in November 2008, from 0.45-1.67 \$ l^{-1} in Sudan and Malawi respectively (GTZ 2009a). Taxes take up a large part of the retail prices, for Tanzania we were able to analyse the breakdown of retail prices. In October 2008 the retail price of diesel in Tanzania was 1.38 \$ l^{-1} while the price per barrel was 70 \$. Government taxes consist of excise duty (0.26 \$ l^{-1}) and road toll (0.17 \$ l^{-1}) and are together 0.43 \$ l^{-1} (Citizen 2008; EWURA 2009). CIF prices include Cost Insurance and Freight, the goods are at the port in Dar es Salaam ready to be offloaded. Table 2B-12, shows the breakdown of the retail price.

Table 2B-12: Breakdown of retail price of diesel in Tanzania, October 2008, (Citizen 2008; EWURA 2009).

	Diesel \$ l^{-1}	Diesel \$ GJ^{-1}[c]
Government taxes	0.43	11.59
Transport[a]	0.01	0.23
Oil dealers profit/margin	0.09	2.43
Local cost payable[b]	0.05	1.28
CIF Dar es Salaam	0.80	21.54
Total	**1.38**	**37.07**

[a] This covers town delivery (10 TZS)
[b] This covers wharfage, destination inspection, Tanzania Bureau of Standards, Tiper fees, demurrage and finance cost, payable to authorities like Energy and Water Utilities Regulatory Authority (Ewura) and Tanzania Ports Authority.
[c] Energy content diesel: 44 MJ l^{-1}, density 850 kg m^{-3}, (Sahoo and Das 2009)

B-2 Input Data Cassava

Transport is an important aspect for cassava cultivation since fresh roots cannot be stored for a long time. The most common mode of transport for areas located at a relatively short distance (20-30 km) from a market is by bicycle, manually carrying bags on the head and by ox chart (Zvinavashe et al. 2011). For larger distances trucks and buses are used (Simwambana 2005; Kambewa and Nyembe 2008). Simwambana (2005) found an average price for transporting cassava of 0.38 $ per 50 kg over a distance of 279 km in Zambia, this is 0.01 $ kg^{-1} or 0.06 $ l^{-1}. Cassava to ethanol *conversion* cost around 0.21 $ l^{-1} according to Nguyen et al. (2008), the conversion steps include; processing into chips, mixing, liquefaction, saccharification, fermentation and distillation. In China, Zhang et al. (2003) estimate the conversion costs at 0.28 $ l^{-1} together. The average of these two studies is 0.25 $ l^{-1} which is used in this study. *Distribution costs* for ethanol are taken from Nguyen et al., they assumed 150 km distance and 10-12 t diesel truck (Nguyen et al. 2008). Distribution covers transport from refinery to a mixing station where ethanol will be mixed with petrol before distribution further to petrol stations.

Table 2B-13: Cassava ethanol costs per litre ($ l^{-1}).

	Low family	Low hired	Intermediate family	Intermediate hired	Petrol
Feedstock	0.15	0.52	0.15	0.36	
Transport to refinery[a]	0.06	0.06	0.06	0.06	
Conversion[a]	0.25	0.25	0.25	0.25	
Distribution[a]	0.01	0.01	0.01	0.01	
CIF Dar es Salaam[a]					0.79
TOTAL	**0.47**	**0.84**	**0.47**	**0.68**	**0.79**

[a] See data input Section for sources

The prices for fossil petrol fluctuated per year and per country. For Tanzania we found detailed data on petrol prices. Government taxes were around 35% of the retail price. Transport expenses for landlocked countries might be considerably higher. CIF price in Dar es Salaam in 2008 was 0.79 $ l^{-1} or 0.26 $ GJ^{-1} when the price per barrel was around 70 $ (0.44 $ l^{-1}), see Table 2B-14 with the breakdown. Using an energy content correction factor of 0.89[3], one kg of cassava could costs 94 $ t^{-1} at competitive prices, this is the upper limit we used in the sensitivity analysis, see Section 2.4.2.

Table 2B-14: Breakdown of retail price of petrol in Tanzania, October 2008, (Citizen 2008; EWURA 2009).

	Petrol $ l^{-1}	Petrol $ GJ^{-1c}
Government taxes	0.45	13.99
Transport[a]	0.01	0.26
Oil dealers profit/margin	0.09	2.81
Local cost payable[b]	0.05	1.52
CIF Dar es Salaam	0.79	24.50
Total	**1.39**	**43.07**

[a] This covers town delivery (10 TZS)

[3] Cassava ethanol has 89 % of the energy content of petrol (Nguyen 2008)

[b] This covers wharfage, destination inspection, Tanzania Bureau of Standards, Tiper fees, demurrage and finance cost, payable to authorities like Energy and Water Utilities Regulatory Authority (Ewura) and Tanzania Ports Authority.
[c] (Hamelinck 2004), energy content petrol (Lower Heating Value) 43.45 GJ t^{-1}, density 745 kg m^{-3}

B-3 Input Data Eucalyptus

The Eucalyptus pellet production chain consists of feedstock, transport and conversion. Batidzirai et al. (2006) calculated *transport* expenses for Eucalyptus in Mozambique. They distinguish transport from fields to a central gathering place (15 km), then to a central processing unit (100 km) and further to the nearest port (329 km). Transport is done by truck, train and domestic ships, the average costs of transportation from field to port (9 chains), are 24 \$ t^{-1} or 1.24 \$ GJ^{-1}, which is used in this study. These data are in line with results from Nhancale *et al.* (2009), who reported a cost of 692 \$ for a 25 ton trailer for transport regardless the amount of km, which equals 28 \$ t^{-1}. Jeje *et al.* (1998) mention that transport and handling costs (of a commodity product) between the port and farmgate can add up to 31-64% to the retail price. *Conversion* costs are about 21 \$ t^{-1} according to Batidzirai (2006) or 1.08 \$ GJ^{-1}, which is based on sizing, densification and drying. In North America FOB prices for pellets range currently between 135-140 \$ t^{-1} (56-58 \$ m^{-3}) (Sikkema et al. 2010). And prices for pellets are around 160 \$ t^{-1} CIF Rotterdam. Calculated for East Africa (FOB), this equals about 100 \$ t^{-1} (42 \$ m^{-3} or 5.1 \$ GJ^{-1}) considering 53 \$ t^{-1} freight and 7.4 \$ t^{-1} handling and storage costs (GF Energy 2010). This price is used as default value in our study.

Table 2B-15: Eucalyptus pellets costs per ton (\$ t^{-1}).

	Low family	Low hired	Intermediate family	Intermediate hired	Pellets
Feedstock	8	15	6.	12	
Transport to port[a]	24	24	24	24	
Conversion[a]	21	21	21	21	
FOB East Africa[a]					100
TOTAL	**53**	**60**	**51**	**57**	**100**

[a] See data input Section for sources, data is rounded

Prices for wood products other than fuel wood and pellets

Prices of wood for poles are higher but the rotation period is longer, prices are e.g. 16 \$ m^{-3} in Tanzania (Wiskerke et al. 2010), 44-107 \$ m^{-3} in Ethiopia (Jagger and Pender 2003) and 259-548 \$ m^{-3} in Zimbabwe (Mabvurira and Pukkala 2002) depending on the size of the poles. Wood for timber production has a relatively high market value. In Mozambique communities often sell to local saw mills, prices range from 2-10 \$ log^{-1} (17.5-210 \$ m^{-3}) (Nhancale et al. 2009).

3 Comparative analysis of key socio-economic and environmental impacts of smallholder and plantation based jatropha biofuel production systems in Tanzania

JANSKE VAN EIJCK, HENNY ROMIJN, EDWARD SMEETS, ROB BAILIS, MARTIJN ROOIJAKKERS, NELLEKE HOOIJKAAS, PITA VERWEIJ and ANDRÉ FAAIJ

Biomass and Bioenergy (2013) 61, 25-45 [4]

Abstract
Two jatropha business models are compared on seven key sustainability areas of concern, which are operationalized into various quantitative and qualitative indicators. The assessment is based on two Tanzanian real-life cases, a wide range of primary and secondary sources are used. Results indicate that both the decentralized smallholder model and the centralized plantation model can lead to positive socio-economic and environmental impacts, but substantial differences are also apparent. The smallholder model scores better on land rights, GHG balance and biodiversity and it reaches more people, whereas the plantation model creates more employment and higher (local prosperity) benefits for smaller numbers of people, and could lead to higher yields. Negative impacts of the smallholder model are minimal, whereas the plantation model could lead to decreased food security, loss of land rights and biodiversity. This could permanently affect the livelihood situation of the local population, but this is not inevitable as there is considerable scope for implementing mitigating policies. The way in which a particular model is implemented in practice, its management and company values, can have a major influence. However, the biggest hurdle towards achieving sustained positive societal impacts in both models is their marginal profitability at current yields, costs and prices. Still, these results are highly sensitive to uncertain yields and oil prices. Better outcomes in the future are therefore not foreclosed. A reliable sustainability assessment requires many location-specific and operational company data. More quantitative indicators are ideally required to improve assessment of social impacts and effects on environment.

[4] This chapter is partly based on research funded by NL Agency and GEF UNEP/FAO/UNIDO

3.1 Introduction

The use of biofuels can potentially contribute to climate change mitigation, rural development and energy security. One source for biofuel is jatropha, a perennial shrub that grows pan tropically, whose seeds contain oil that can be used as a diesel substitute. Early this century jatropha attracted a great deal of attention by investors (Cotula et al. 2008; GEXSI 2008; Gordon-Maclean et al. 2008; Romijn and Caniels 2011). Allegations about yields of up to 10 t seeds ha^{-1}(Openshaw 2000), or 5 t seeds ha^{-1} on average (Francis et al. 2005), low nutrient requirements, and little need for care in combination with ability to withstand semi-arid conditions raised high expectations regarding its Straight Vegetable Oil (SVO) and biodiesel potential (Brittaine and Lutaladio 2010). But the realized plantings have been much more modest. The global financial crisis caused difficulties in financing. More accurate research also emerged, warning that realistic yields from an undomesticated crop would be only around 1000 kg seeds ha^{-1} (Van Eijck et al. 2010), and that the crop would not perform in poor conditions without adequate nutrient and water management (GTZ 2009b). Concerns were also raised about socio-economic impacts of large plantations, especially local food security (Mitchell 2008b; World Bank 2010b). Positive livelihood impacts on smallholders also began to be questioned, mainly due to severely disappointing yields (Ribeiro and Matavel 2010).

However, that does not mean that jatropha projects cannot have positive effects at all. So far, study results have remained inconclusive, partial, and in mutual disagreement on many fronts. There is a definite lack of studies assessing project sustainability comprehensively. For instance, although several studies have reviewed agronomic aspects, livelihood impacts and/or the economic viability of several jatropha case studies (Tomomatsu and Swallow 2007; Loos 2008; GTZ 2009b; Ariza-Montobbio and Lele 2010; Brittaine and Lutaladio 2010), they have not examined ecological impacts. Other studies have looked at environmental aspects (Finco and Doppler 2010; German et al. 2011b) and land rights (Salfrais 2010), but without assessing economic viability. Comparisons of the two most common business models, plantations and smallholder systems, are particularly scarce, although some studies suggest major impact differences (ProForest Ltd. 2008; Achten et al. 2010; Brittaine and Lutaladio 2010). One major obstacle is that big plantations are wary to share key financial performance data. Only a few studies, all focused on Mozambique, have reviewed impacts by large plantations (Mota 2009; Peters 2009; Spöttle et al. 2011), but these studies are not comparative since hardly any smallholder projects operate there. Broadhurst's Tanzanian study (Broadhurst 2011) is a good comparative attempt, but his study lacks an economic viability assessment. Many studies also have not used systematic qualitative and quantitative impact indicators.

This article aims to conduct a methodologically rigorous and detailed comparative assessment of the major socio-economic and environmental impacts caused by two major different jatropha business models, using two projects operating in Tanzania as case studies: a large centralized plantation and a smallholder (hedge) system organized around a central processor. In order to create a comprehensive and yet practically applicable list of sustainability indicators, we identified “seven key areas of concern” that are mentioned by different sustainability certification initiatives. For each of these, qualitative and - as much as possible - quantitative impact indicators were formulated. Data were drawn from a wide range of published and grey literature, company documents, personal interviews, satellite data and own field measurements. A mix of quantitative and qualitative methods was used to assess the impacts of the projects according to the chosen indicators. This included, among others, detailed financial feasibility estimations and GHG estimations, including land use change effects. Primary data collection took place in May-August 2010 at the plantation company and during 2006-2010 at the oil processor that coordinates the smallholder system.

The principles, criteria, indicators and methods used in the analysis are described in Sections 3.2.1 and 3.2.2. Then follows a description of the plantation and smallholder-based models in Section 3.2.3. Section 3.3 presents the results of the analysis for each of the seven areas of concern. Section 3.4 contains the discussion and conclusions. Methodological details and background statistics are provided in Appendices A to F.

3.2 Approach and methodology

3.2.1 Selection of principles, criteria and indicators

The principles/criteria and indicators/parameters shown in Table 3-1 were derived from various certification initiatives, policy documents and scientific literature in which the sustainability of bioenergy systems is researched (see (van Dam et al. 2010b) for a comprehensive review of such initiatives in 2010). In some certification systems a distinction is made between (more general) principles and (more specific) criteria. However, this distinction is often vague; therefore we use a combined category “principles/criteria”.

A large number of certification initiatives are being developed and applied. These initiatives vary with respect to scope, issues addressed, and criteria and indicators included. Our focus is on widely recognized frameworks such as: the Cramer criteria (Cramer et al. 2006; Brose et al. 2010) operationalized in the NTA8080 (NEN 2009), the Roundtable on Sustainable Biofuels (RSB) (RSB 2010) and the Global Bio Energy Partnership (GBEP) (GBEP 2011). We also examined the Renewable Energy Directive (RED) of the European Commission (2009/28/EC 2009), the Position Paper of the WWF with options to promote sustainability (WWF 2008) and the Draft National Biofuels Guidelines of Tanzania (MEM 2008). The RSB is currently considered as one of the most widely acknowledged and most comprehensive certification schemes (Froger et al. 2010; van Dam et al. 2010b; Vissers et al. 2011). In July 2011, the European Commission officially recognized its compliance with its Renewable Energy Directive 2009/28/EC (Roks 2010; RSB 2010; Ismail et al. 2011). The GBEP has compiled 24 sustainability indicators (May 2011) which are currently being operationalized and also widely acknowledged (GBEP 2011). We deliberately did not confine ourselves to using one specific system, as this would be arbitrary and might result in a potentially biased assessment. Moreover, socio-economic impacts of bioenergy production are hardly included in existing initiatives, despite serious concerns (van Dam et al. 2010b). We did want to address socio-economic issues in this study.

First, the areas of concern were identified that are most frequently mentioned in these certification initiatives and in the scientific literature (see(Lewandowski and Faaij 2006; Diaz-Chavez 2010) for an overview of all potentially relevant areas of concern). A few of those, especially water, soil, air and gender issues, could not be taken into account in this study due to data constraints for the two projects in Tanzania and a lack of suitable indicators. For each chosen area of concern one or more principles/criteria were then selected (Table 3-1).

Table 3-1: Overview of principles/criteria, indicators/parameters, method of analysis, and data sources used in the analysis (Cramer et al. 2006; Lewandowski and Faaij 2006; MEM 2008; Smeets et al. 2008; WWF 2008; 2009/28/EC 2009; GBEP 2009; RSB 2010; GBEP 2011)

	Principle / criteria	**Indicators / parameters / verifiers**	**Analysis**	**Data collection**
	The production of bioenergy shall:			
Socio-economic areas of concern:				
1. Economic feasibility	be financially feasible	NPV [$ ha^{-1}][a], IRR [%][a], PBP [yr][a], production costs [$ l^{-1}]. NPV and IRR should be positive and PBP and production costs competitive	Quantitative (economic modelling)	Fieldwork (in 2006-20010) and company documents
2. Local prosperity[b]	contribute to the social and economic development of local, rural and indigenous peoples and communities	<u>Wages and employment:</u> Employment opportunities, unemployment rate in the region, additional income for smallholder, wage categories for employees [$]. <u>Impact on local economy</u>; Total investment costs [$], total (discounted) costs [$], investments in health care and	Qualitative and quantitative	Company business plans, interviews with the communities, literature including household surveys, and national

		education facilities, infrastructure, purchase of local materials, expenses that stay in local economy [%], origin of employees[c], region or nation of origin social wellbeing; perception of local population, risks for population if project is abandoned		statistics.
3. Labour and working conditions	ensure decent work and the well-being of workers	Compliance to and description of: legal issues, child labour provisions, discrimination, forced and compulsory labour, disciplinary practises, safety, freedom of trade union organisation, education/training. working hours, secondary benefits[d]	Qualitative	Company documents, literature, visits and interviews with management.
4. Food security[e]	not endanger food security	Qualitative description of; current food security status, possible threats to decreased food availability, access, stability and utilization and measures taken to increase food security	Qualitative and quantitative	Statistical data, literature and observations
5. Land ownership and land rights[f]	not violate land rights	Land procurement procedures; land transferred [ha], compensation payments [$]; displacement of people; process transparency; risk in case of discontinuation; public opinion	Qualitative	Literature, observations
Environmental areas of concern:				
6. Greenhouse gas balance and carbon stock changes	contribute to reducing GHG emissions compared to fossil fuels and contribute to reducing fossil fuel use	Above- and below ground carbon stock ; Life-cycle GHG emissions [CO_2-eq]	Quantitative	at plantation site: satellite data calibrated with field measurements
7. Biodiversity	shall avoid negative impacts on biodiversity, ecosystems, and areas of High Conservation Value	Conversion of vegetation; location of production areas related to various biodiversity maps; occurrence of threatened species; species diversity (Shannon, Sørenson index)	Qualitative and quantitative	GIS analysis, observations and literature

[a]: A Net Present Value (NPV) > 0 and an Internal Rate of Return (IRR > the (real) discount rate, constitute minimum requirements for project profitability, as well as a reasonable Pay Back Period (PBP), the number of years needed to recover the initial project investment. The total production costs per litre SVO are useful for comparing efficiency of the two business models. They mainly comprise investments in farming support, processing, storage / transport and general investments. For calculation of the total production costs per litre, fixed investment costs are levelised over the 20 year project period. For formulas, see (Van Eijck et al. 2012).
[b]: Background indicators used for local prosperity: Gross Domestic Product (GDP); GINI coefficient (UNDP 2011); Human Development Index (HDI) (UNDP 2011); % people below the Tanzanian national poverty line; %

people below US$ 2.00 per day (UNDP 2009); % people below the extreme poverty line of US$ 1.25 (PPP) (UNDP 2011); Multidimensional Poverty Index (UNDP 2011); Poverty Gap Ratio (UNSTATS 2011); minimum wage [$]; % own-account and contributing family workers in total employment, based on (UNSTATS 2011); household possessions; and literacy rate [%]. Definitional details in Appendix A-2.

[c]: The origin of the employees is analysed to see if the wages earned are likely to be spent in the local economy, or that they are likely to leak out to other countries/regions.

[d]: These indicators are based on the UN Universal Declaration of Human Rights (1948), which is a requirement by the NTA8080 (NEN 2009) and the "Tripartite Declaration of Principles concerning Multinational Enterprises and Social Policy", set up by the International Labour Organization (ILO 2006). Other benefits: (Smeets et al. 2008). Safety is also mentioned by (Lewandowski and Faaij 2006; GBEP 2011).

[e]: Background indicators used for food security: food security situation Tanzania; change in production of main staple crops [%]; food price index, change compared to overall price index [%].

[f]: Background indicators used for land rights: number of land certificates handed out; number of land conflicts; dissolving rate.

For each principle/criterion one or several concrete, measurable indicators were defined or compiled, which are used to evaluate to what extent the principles/criteria are met. For working and labour conditions, only compliance or descriptive indicators were selected because it is not possible to compile measurable indicators for this area of concern (see e.g. Woods and Diaz-Chavez (2007) for a discussion about the use of indicators). The selection and formulation of principles/criteria and the definition of indicators are detailed below for each area of concern.

3.2.2 Description of main indicators and assessment methods

3.2.2.1 Economic feasibility

In order to assess the economic sustainability of our cases we conduct a Cost Benefit Analysis (CBA), in which the Net Present Value (NPV), the Internal Rate of Return (IRR) and the Pay Back Period (PBP) are used as indicators (Meredith and Mantel 2011; Van Eijck et al. 2012). The CBA is performed assuming similar total cultivation areas of 80,000 ha and a 20 year lifespan for both cases. The 80,000 ha corresponds to the original business plan of the plantation company and is also broadly compatible with the goals set by the processor in the smallholder-based system (Diligent 2008; BioShape 2009). The 80,000 ha size assumption is also used to assess impacts on local prosperity, food security and the environment.

In the plantation model, the choice of harvesting system is expected to have a large impact on total employment, and thereby on regional economic impacts. Therefore, two harvest-system scenarios are worked out for this model: "semi-manual" and "fully-mechanized". For the smallholder-based system, two different capacity scenarios are elaborated: a "low" base case (88,000 tons of processed seed/year) and a "high" case (160,000 tons of seeds/year). The "low" scenario assumes a low-input cultivation regime and low per-ha yields for the smallholders, whereas the “high” scenario is compatible with intermediate input cultivation (Van Eijck et al. 2012).

A sensitivity analysis is performed with respect to CO_2 credit price, SVO price, discount rate, and - for the smallholder model - the purchase price of seeds. In the plantation system various yield scenarios are analysed, as well as a scenario in which proceeds from harvested wood from land clearing are incorporated (as stipulated in the original business plan). A full list of CBA assumptions is contained in Appendix A.

3.2.2.2 Local prosperity

Local prosperity can be increased if household income is increased through employment or increased earnings. The focus in this analysis is on income-effects from employment and their impacts on the local economy. Furthermore, a qualitative description of the impact on social well-being is added. Because the projects had not reached their full size at the time of this assessment, this analysis is partly prospective.

3.2.2.3 Labour and working conditions

Labour and working conditions relate to the way hired employees are treated, and how smallholders could be influenced in their working conditions. Most of the indicators are compliance indicators: the presence of specific policies on discrimination, disciplinary procedures and the possibility to join a labour union was checked. Various operational company data were used for this.

3.2.2.4 Food security

It is explored if either model of biofuels production threatens to decrease food security in any way, or, if so, how the scheme proposes to mitigate the threats. The RSB proposes that biofuel producers take measures to “enhance the local food security of the directly affected stakeholders” (RSB 2010). Therefore, it is also explored whether the scheme proposes to improve food security beyond current levels. The current status of the case study regions along the spectrum of food insecurity and malnutrition is investigated first. This is done with biometric measures taken from existing data sources: weight-for-age (McKinney 2006; UNICEF 2007); wasting or stunting; and vulnerability. Vulnerability is determined by looking at the five vulnerable livelihood groups that are identified in Tanzania by McKinney (2006); poor-income people (income mostly from crop production), wage labourers, small farmers, remittance dependents and natural resource dependents. Threats to food security arising from the projects are analysed next, by looking at its different dimensions distinguished by FAO: availability, access, stability of supply, and utilization of food for individuals, households, communities and larger population groupings (FAO 2010b; UNFAO 2010). Stability of food supply relates to both availability and access. If groups are affected through big changes in either price or access to supply, then they lack stability and may suffer from food insecurity (RSB 2011). Utilization relates to food quality, preparation, and storage, as well as nutritional knowledge and health status of the population (RSB 2011). Biofuel activities could affect this through impacts on availability of essential inputs to food preparation, like water and fuel.

3.2.2.5 Land ownership

In African countries land rights are typically embedded in complex legal frameworks (Sulle and Nelson 2009a). In Tanzania informal customary land laws co-exist with formal land title deeds, which is why transferring land is complex and sensitive. The main issues are: the land acquisition process (possibly involving deviations from legally established routes); land compensation payments (undervaluing the land); transparency of the process (possibly leading to misunderstandings and disagreements about compensation eligibility); and impacts on livelihoods (Sulle and Nelson 2009a; Sulle and Nelson 2009b; Vermeulen and Cotula 2010b). Furthermore, promises made by projects to villagers are often not written down and therefore cause skepticism amongst farmers when expectations are not met (Sulle and Nelson 2009b). Therefore the following processes are evaluated: land procurement procedure; change in land access; amount of ha transferred; compensation paid; transparency of process; potential risk in case of project failure; and public opinion in Tanzania. Our main data sources were operational company data and external reports.

3.2.2.6 GHG balance and carbon stock

Standard GHG methodology is used, e.g.(Franke et al. 2012). In the smallholder system, GHG emissions from changes in above or belowground biomass, soil organic matter and litter are negligible, assuming jatropha is planted as hedgerows in addition to current crop cultivation, thus avoiding conversion of forest and existing cropland. For (large scale) plantations, the emissions from changes in land use are evaluated by estimating the difference in carbon stock between the prior natural vegetation and the jatropha plantation. The carbon stock of the natural vegetation is estimated as follows:

- *Aboveground biomass* is calculated using remote sensing data in combination with field measurements, as applied by e.g. (Muukkonen and Heiskanen 2005; Maselli et al. 2009). A satellite map was used to calculate the Normalized Difference Vegetation Index (NDVI), this is validated by measuring the harvested and dried above-ground biomass of 10 plots (20 × 20 m) for each of the four most common vegetation classes which are woodland, open forest, forest and dense forest (so 40 plots in total). Where available, specific wood densities were used to determine the carbon stock of trees. Shrubs and small trees were weighed and dried in a kiln to calculate the dry biomass per ha. Grass was sampled in subplots of 5 by 5 m, and sundried. The aboveground biomass measurements were linked to the NDVI values from remote sensing by means of a linear regression analysis. Next, the NDVI map was converted into an aboveground carbon map using the regression equation: NDVI = (NIR − VIS)/(NIR + VIS) in which NIR is the near infrared part of the spectrum, and VIS is the visible part of the spectrum of light (Ribeiro et al. 2008). This map is used to calculate the total carbon stock of the area assuming all carbon in the biomass is emitted as CO_2 when the land is cleared for the jatropha plantation.

- *Belowground biomass* is estimated using the data on above ground biomass and the default IPCC factors for the above/belowground biomass ratio.
- *Dead organic matter* (dead wood and litter): value taken from literature.
- *Soil organic matter* (carbon in soil): value taken from literature. The timeframe for inclusion of the change in carbon stock is 20 years.

The GHG reduction is then calculated using **Equation 3-1** below.

Equation 3-1

$$GHG\ reduction\ (\%) = \frac{\mathrm{F} - (-\mathrm{A}+\mathrm{B}-\mathrm{C}-\mathrm{D}-\mathrm{E})}{\mathrm{F}} * 100$$

GHG emissions/absorption from:
A: Removal of original vegetation
B: Jatropha growth
C: Transport
D: Conversion to jatropha oil
E: Transport to end-user
F: Application of the jatropha oil / fossil reference[5]

Values from literature are used to determine lower and upper ranges for each item, the timeframe is 20 years. No useful application of the removed vegetation, mainly hulls used as a fertilizer, and seedcake used as a fertilizer, is assumed except for the upper range calculations.

3.2.2.7 Biodiversity

One of the key strategies to mitigate the risk of bioenergy projects to biodiversity is to conserve areas of significant biodiversity value (Hennenberg et al. 2010). The risk of plantation establishment to areas of significant biodiversity value is assessed by identifying the location of national protected areas (WDPA 2010). Furthermore, additional areas of significant biodiversity value are considered, as identified by

[5] GHG emissions from the fossil reference related to the application of the oil (e.g. fossil diesel if jatropha oil is used as transport fuel, other purposes are heating/cooking).

Biodiversity Hotspot Areas (Conservation International 2007), Key Biodiversity Areas according to Birdlife International (IBAT 2008), and Critical Ecoregions (WWF 2010). The location map of the plantation was overlaid with these maps. Overlap indicates potential risk of reduced biodiversity if the land is converted to biofuel cultivation.

The shrub and tree diversity of the planned plantation area are assessed using the Shannon-index (Shannon 1948) to account for abundance and evenness of the species present, and the Sorensen-index (Sorensen 1948) to indicate similarities between vegetation types; see Appendix F for the formulae. These two indexes do not have a threshold value but are compared to values reported in the literature, to assess the degree of degradation of the initial vegetation.

Conversion of natural vegetation into plantations containing species with limited distributions could result in (local) species extinction. Therefore, the presence of endangered and endemic species is evaluated by indicating in the 40 plots that were assessed, all trees exceeding a DBH of 10 cm with their Kiswahli names with the help of a local expert followed by identification of their botanical names. The species names are checked with the IUCN Red List of Threatened Species (IUCN 2010).

The indicators used to assess impacts on biodiversity can thus be compared to elements of the concept of a high conservation value (HCV) area initially developed by the Forest Stewardship Council (FSC 1996) in its standard on sustainably managed forests. This concept includes different conservation values of global and national importance that are based on species, sites, ecosystems, and values corresponding to ecosystem services, in particular HCV criteria 1-3 (Jennings et al. 2003).

3.2.3 Selection and description of the two bioenergy production systems and settings

3.2.3.1 Case study region

Two Tanzanian cases were chosen for the following reasons: first, in Tanzania there are different jatropha business models in operation which makes the comparison realistic. Second, jatropha projects in this country started as early as 2005, so a lot of experience has accumulated. Third, the Tanzanian government has been working on an enabling environment for biofuels and is distinguishing in its policies between plantations and smallholder schemes (MEM 2008). Two real-life jatropha production systems were investigated: a plantation company in the Southeast of Tanzania, BioShape Tanzania Ltd., and a decentralized smallholder system with a central oil processor located in the North of Tanzania, Diligent Tanzania Ltd. The smallholder system covers a much larger sourcing area than the concentrated plantation, see Figure 3-1.

Figure 3-1: Overview of Tanzanian districts that are covered by Diligent Tanzania ltd (smallholders) and BioShape (plantation) in 2009.

3.2.3.2 Smallholder (hedgerow) system

In the smallholder (hedgerow) system, farmers produce for the processing company either under contract (also called outgrowing or contract-farming) or independently. Mostly, family labour is used. The jatropha hedgerows are planted around homesteads or agricultural plots. One farmer can plant the equivalent of around 0.5-1 ha with jatropha, with on average 1000 plants per plot. The seeds are sold to the processor company directly or through a collector who adds a commission to the seed price. Cultivation of jatropha is not very profitable for smallholders, but in many cases it is attractive enough due to low opportunity costs for labour and hedge land (Van Eijck et al. 2012).

Collection centres run by collectors are located near strategic places such as in a grocery shop, a school or at the house of a well-known farmer. Farmers bring their seeds in bags using bicycles, ox-charts or other local forms of transport. The company organizes onward seed transport to the central processing unit in Arusha, using local transport companies. A “backhaul system” is used for this, utilizing trucks that would otherwise return empty to town after delivering their products upcountry. The processor provides the farmers and collectors with extension services and initial planting material (farming promotion). The processor employs a field team for promotion of the crop, and technical staff in the factory. The processed products are used for the domestic and international market.

Diligent started its activities in 2005 and continued to the end of 2012 when one major investor pulled back. The activities, collection and processing, still continue but under new ownership and name. At the time of study in 2006 the company was working with around 4000 smallholders (reaching 40,000 by 2011), produced around 35,000 l SVO annually and employed around 35 people. The goal at the time of study was to reach 10,000 and ultimately 50-200,000 ha over 20 years; an expansion to 80,000 ha is assumed here to enable comparison with the plantation.

3.2.3.3 Plantation system

In the plantation system the land is owned by the company BioShape and hired employees cultivate monoculture (block) plantations of 200 ha each. Agricultural equipment and trucks used for cultivation and transport are also owned by the company. Harvesting is done semi-manually, with tree shakers (=our base case scenario). Fully mechanized harvesting is also considered, but these technologies are not yet fully developed. The original business plan envisaged export of unprocessed seeds to Europe, but later plans allowed for domestic seed processing, as requested by the Tanzanian Ministry of Energy and Minerals (MEM 2008). At the time of study (2009) BioShape had planted 400 ha, acquired 34,000 ha, and employed around 400 casual and contract workers. It aimed at 80,000 ha under cultivation by 2018 (BioShape 2009). By the end of 2010 activities halted for various reasons, amongst others the financial crisis. However, the financial model reported here is based on the assumption of a fully executed business plan.

More details about the business models are given in Table 3-2.

Table 3-2: Key characteristics of the two business models used in the analysis

Business model → Characteristic↓	**Smallholder-based model**	**Plantation model**
Mode of planting	Hedgerows	Monoculture
Type of labour	Family labour or occasional hired labour on the farms, and employees in the processing factory and field team	Employees
Area under cultivation	80,000 ha	80,000 ha
Beneficiaries	80,000- 160,000 famers (each 0.5-1 ha) and employees (≈500est.)	employees (10-35,000)
Yield	1.1 ton ha^{-1} yr^{-1} as the base case ('low' yield scenario), or 2 ton ha^{-1} yr^{-1} ('high' yield scenario), see (43)	1.1 ton ha^{-1} yr^{-1} as the base case; 2, 4 and 6[a] ton ha^{-1} yr^{-1} in the sensitivity analysis
Processing capacity	88,000 ton seeds yr^{-1} as the base case (low yield scenario) 160,000 ton seeds yr^{-1} (high yield scenario)	88,000 ton seeds yr^{-1} as the base case; reaching up to 480,000 ton seeds yr^{-1} at 6 ton $ha^{-1}yr^{-1}$[a] in the sensitivity analysis
Mode of harvesting	Fully manual	Semi-manual (base case) or fully

		mechanised
Processing	In Tanzania	Initial plan: Western Europe; later changed to Tanzania (34)
Products	Jatropha SVO and biodiesel, seedcake briquettes and charcoal	Jatropha SVO and biodiesel, seedcake briquettes and charcoal, jatropha seeds, harvested wood from plantation

[a]: Six ton ha^{-1} yr^{-1} is the original yield estimate in BioShape's business plan (BioShape 2009).

The analysis includes land clearing and preparation (plantation only), the production and transport of the feedstock, conversion into biofuel, and transport to end users. Applications considered are Straight Vegetable Oil (SVO) for local use and export (both models). Co-products from biofuel production (seedcake and husks) are used as alternatives to wood and/or charcoal, e.g. in boilers, and as a fertilizer. The timeframe of our analysis runs from 2005 to 2025, when both models reach maximum production capacity with mature trees.

3.3 Results

3.3.1 Economic feasibility

The results of the economic analysis are presented in Table 3-3 and Figure 3-2. The total investment costs (excluding general expenses) amount to US$ 11 m for the smallholder model and US$ 32 m for the plantation. The total (discounted) costs over a 20 year lifetime are US$ 77-130 m for the smallholder model and US$ 107-125 m for the plantation.

Table 3-3: Main results of the economic analysis

System	NPV (US$m ha^{-1})	IRR (%)	PBP (yr)	Discounted production costs US$/l SVO
Plantation				
Semi-manual (1 t/h), base case	15	17	13	1.32 [a]
Fully mechanized (1 t/h)	-3	7	≥20	1.45
Processing with smallholders				
Low capacity 82,000 ton seeds, base case	8	14	13	1.28
High capacity 160,000 ton seeds	18	18	12	1.20

[a] US$ 0.87 if wood sales revenues are deducted from production costs.

With (semi)manual harvesting, both business models are marginally profitable. Interestingly, these base case profitability estimations for the two models are quite similar, even though their land, capital and labour configurations differ considerably.

The estimated PBPs of 12-13 years are long especially in the context of developing economies where risks are high, and even more so in view of the lack of commercial experience with jatropha as an energy crop. Both base case models have low IRRs: The low capacity smallholder system with yields of 1.1 ton seeds ha^{-1} y^{-1} has an IRR of 14%, and the plantation with the same yield and semi-mechanized harvesting yields 17%. This is dangerously close to the real discount rate of 8.2%. The best IRR of 18% occurs in the "high" scenario of the smallholder model. Fully mechanized harvesting in the plantation model is expected to be unprofitable. However, the plantation profits are much higher if wood sales from land clearing during the first 11 years of the project (approximately US$ 27 m) are included. If these revenues are deducted from the costs of production, the cost per litre SVO falls spectacularly from US$ 1.32 to US$ 0.87. However, this scenario is not informative about the profitability of jatropha cultivation as such.

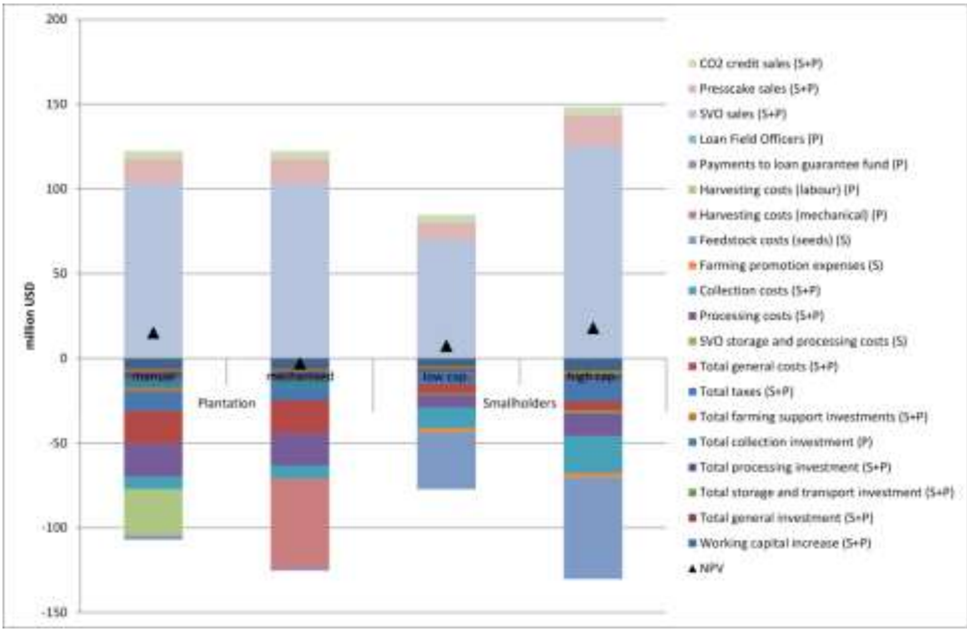


Figure 3-2: Discounted production costs, revenues and NPVs for the two models (2 scenarios each). S indicates cost factors specific to the smallholder model, while P indicates plantation-specific cost factors. S+P means that the relevant cost factors apply to both models.

The results discussed above still include uncertain benefits from carbon credits. Voluntary Credits (VCAs) are being traded at other jatropha plantations, but their price can sink to a low US$ 2-3 per ton. Therefore, in the sensitivity analysis (Table 3-4), the effect on profitability of the removal of the CO_2 credits has been assessed. The sensitivity analysis also assesses effects from variations in seed yield and the oil sales price, as these are also uncertain.

Table 3-4: Sensitivity of profitability to changes in CO_2 credit revenue, SVO price, discount rate, seed purchase price, seed yield and the inclusion of wood sales (Pl= Plantation model, Sm=smallholder-based model)

Change in variable	Scenarios	NPV [M$]		IRR [%]		PBP [yr]		Production costs [$ l^{-1}]	
	business models ->	Pl.	Sm.	Pl.	Sm.	Pl.	Sm.	Pl.	Sm.
Original value	Semi manual - low capacity Mechanized - high capacity	15 -3	8 18	17 7	14 18	13 >20	13 12	1.32 1.45	1.28 1.20
Reduction of CO_2 revenue from US$ 350,000 yr^{-1} to US$ 0.	Semi manual - low capacity Mechanized - high capacity	11 -7	4 14	15 5	11 16	14 >20	16 13	same	
Unchanged SVO price at US$ 2 ton^{-1}, instead of decrease over time to US$ 1 $ ton^{-1}	Semi manual - low capacity Mechanized - high capacity	49 32	35 68	26 19	23 27	11 14	11 11	1.28 1.41	1.35 1.31
Increase in discount rate from 8.2% to 15%	Semi manual - low capacity Mechanized - high capacity	2 -9	-1 3	17 7	14 18	16 >20	>20 16	same	
Increase in seed purchase price from smallholders from US$ 0.16 to US$ 0.20 kg^{-1}	low capacity high capacity		2 8		10 13		16 14		1.38 1.30
Yield increase in the semi-manual plantation system from 1.1 to 2, 4 and 6 ton $ha^{-1}yr^{-1}$	2 ton/ha/yr 4 ton/ha/yr 6 ton/ha/yr	41 98 155		22 26 27		11 10 10		1.13 1.06 1.04	
Inclusion of wood sales of 12.7 m2 of harvestable timber/ha from original vegetation at plantation.	US$ 61.70 gross margin of timber sales per cubic metre	42		91		3		0.87	

Profitability is apparently sensitive to the SVO price. In the original estimation, that price is assumed to decrease over time from US$ 2000 to US$ 1000 per ton. This was assumed because the market for jatropha oil is still immature, with limited supply in relation to demand. One might expect the price to decrease over time to a competitive level comparable to fossil diesel (of around US$ 0.80-1.00 l^{-1} (Van Eijck et al. 2012)). If the SVO price was to remain at US$ 2000 ton^{-1} (≈1.91 $ l^{-1}) until 2025, the projects' financial prospects would be substantially better. In practice, the SVO price will depend closely on the fossil fuel price. If the latter rises over time due to structural high demand on world oil markets, the SVO price may remain well above US$ 1000 per ton.

An increase in the purchase price of seeds from the smallholders and an increased discount rate have smaller influences on profitability. An improved yield per ha would have major positive effects on the plantation project, but this might only be possible against higher input costs (these effects not assessed here).

3.3.2 Local prosperity

All general background prosperity indicators considered for this study indicate that Tanzanian material living standards are extremely low. A large proportion of the population live below the international and national poverty lines: 97% earns less than US$ 2 PPP (2000-'07), 68% is below US$ 1.25 PPP (2000-'09) and 33% is below the national poverty line (2000-'09). Average income in 2009 was a mere US$ 548 per capita. Just 55% of households own a radio, a mere 2.0% own a mobile phone, 5.8% a wheelbarrow, 43% a bicycle, and 1.1% a TV (CountrySTAT 2006). There are also notable differences in poverty between regions and groups ($GINI_{2011}$ = 37.6), which means that some regions and groups are even worse off; see Appendix B for more poverty statistics.

The impacts on local prosperity by the smallholder system and plantation system are detailed in Table 3-5.

Table 3-5: Comparison of local prosperity effects of the two business models

Local prosperity Comparison	Indicator	Smallholder-based model	Plantation model
Wages and employment	Employment	126 field officers, and part time occupation for 80,000-160,000 self-employed farmers	81 field officers and 10,000 - 35,000 employees, mostly low skilled for harvesting, see (66); 6000 employees if harvesting is fully mechanized[a].
	Wages	Above minimum wage for employees; Farmer seed sales revenue: US$ 70-140/year, based on US$ 0.14/kg[b]. Occurrence of middlemen and low seed payments are issues	Above minimum wage
Impact on local economy	Total investment costs	US$ 11m	US$ 32m
	Total costs (discounted) (20 yrs)	US$ 77-130m (US$ 33-59 is spent on purchasing seeds from farmers and US$ 4.8m on transport within region)	US$ 107-125m

	Education and health investments Local purchases % of costs related to processing	No foundation established yet, but plans exist Large complex equipment imported, all else purchased locally 11%	Through foundation: maternity ward, classrooms, vegetable garden. With land acquisition money: classrooms, tractor, see (Chachage and Baha 2010). Small equipment, tools and stationery purchased locally or elsewhere in Tanzania, all large equipment imported 18-20%
Origin of employees	Management functions by local population	1 out of 4 management positions fulfilled by expats, foreign shareholders	Unskilled from the region, skilled from outside, 7 out of 18 management positions fulfilled by expats, foreign shareholders
Social wellbeing	Perceptions about project, incl. perception of risk when project would be abandoned Impact if project fails	Extension service to farmers and facilitation of credit access fosters farmers'perceptions of increased wellbeing and trust; see (74). Skepticism possible if project would be abandoned Possible to take up 'old lives' again, little change in daily routine	Not studied. Increased income might lead to increased social wellbeing, but high levels of skepticism/anger if project is abandoned[c] Difficult/impossible to go back to 'old lives', major disruption.

[a]: Fully mechanized harvest requires around 180 harvesters with 3 workers per harvester, so around 540 workers instead of 24,400 if 88,000 tons of seed production is harvested with an efficiency of 40 kg person $^{-1}$ day^{-1} for 90 days per year (FACT Foundation 2010).

[b]: If the price of seeds is 0.14 \$ kg^{-1}, [a] total amount of 15 kg would have to be collected daily to earn on the poverty line of 2 \$ day^{-1}. An average is 40 kg day^{-1} (FACT Foundation 2010), so this seems achievable for around 25 days per year even without other income.

[c]:This actually happened in 2010, when the Dutch holding of BioShape went bankrupt, and all activities in Tanzania stopped, included the activities of the social benefits foundation, see (Carrington 2011; Wa Simbeye 2011d).

Especially given the extreme poverty in rural Tanzania, the overall impact on local prosperity can be considered quite positive for both models. They both generate employment and income. The plantation generates higher profits per beneficiary, while the smallholder system has many more beneficiaries but generates lower revenues per person. All wages are above the minimum salary range set by the Tanzanian Government (US\$ 49-245$_{2010}$(Association of Tanzania Employers 2010)). The salary scales for higher skilled labour in the two companies are comparable. In the smallholder system the occurrence of middlemen is an issue, since they could pay seed sellers below the minimum price set by the processor. This has occurred a few times in practice. On the other hand, higher than factory gate prices also have been paid in times of high seed demand.

The plantation company offers more investments in education and health facilities, while the farmers in the smallholder model receive more training, and the use of local transport stimulates local entrepreneurs. In a fully manual harvesting regime, employment requirements at the plantation would exceed available employment in the region which would cause migration of people, this could be a threat to both food and water supplies in the region.

Both models also affect the local economy by purchasing tools and materials locally. Not all the expenditures are local, however. Salaries of non-Tanzanians will (partly) end up abroad, furthermore, since both companies have Dutch holdings it is very likely that the profits after tax deductions will (partly) go abroad as well. All advanced equipment is imported from other countries due to sheer unavailability in Tanzania. The location of processing would have a major influence on the occurrence of local spin-off effects; originally the plantation company wanted to process the seeds abroad, this would mean low capacity building and value added creation inside Tanzania.

Perhaps the greatest risk for social wellbeing emanating from the projects arises from the risk of project failure. This could induce high scepticism in the local population due to unkept promises (Carrington 2011). In the plantation model, the entirely basis of people's livelihoods would also be disrupted; it might not be easy or even possible to revert back to prior livelihoods based on subsistence farming. In comparison, disruptions to livelihoods of the outgrowers in the smallholder model would be much less drastic as jatropha hedge cultivation is an incremental activity for farmers with low risks.

3.3.3 Labour and working conditions

Child labour is common in Tanzania, although prohibited under Tanzanian law. The 2002 Population and Housing Census classifies almost 40% of 9 million children in Tanzania as economically active for most of the twelve months prior to the census reference month. Among those, 16% were classified as doing unpaid work, 12% as working for own benefit and 12% as doing paid work. Even among children aged 5-9 years old, 29% were classified as economically active, of which 40% (363,000 children) on usual status (Ministry of Finance and Economic Affairs 2010).

Neither at the plantation nor at the processor was any child labour observed; worker age was verified by checking ID-cards. In the smallholder system children do usually help with household and agricultural tasks, as is common in low-income rural societies, and observed by Mitchell (2008a), but the money earned by selling seeds is sometimes used for school fees. Helping with farm work does not imply that children do not attend school. All Diligent's outgrowers state that their children attend school regularly. This is in fact a condition for production on contract. But it is more difficult to detect and prevent excessive and exploitative child labour in a smallholder system than in a plantation system. Table 3-6 gives a full comparison of labour and working conditions.

Table 3-6: Labour and working conditions in the two business models

	Smallholder-based model	Plantation model
Legal issues	Obeying all relevant ILO and national regulations	Obeying all relevant ILO and national regulations, however, very poor exit strategy (lawsuits ongoing), contravening article 26 of ILO.
Child labour provisions (children in employment and hazardous work)	None employed (farmers might ask their children to help)	None employed
Discrimination	Fieldofficers from all tribes, substantial number of female employees	Based on skills and talent, not on tribe or gender, although preference is given to local people
Forced and compulsory labour	None	None
Disciplinary practices	Warning system before dismissing	Warning system before dismissing (in practice not always applied)
Safety	Protective wear provided to factory employees	Safety regulations (but unclear and no processing took place yet)
Freedom of trade union organisation	Freedom of association/right to organise; contacts with labour unions	Freedom of association/right to organise; contacts with labour unions
Education/training	Courses provided depending on skills (computer, human resource, also HIV/AIDS)	No specific training programme but training on the job
Working hours	Normally 5.5 days a week, overtime is paid 150% or 200% (Sunday). Overtime and night shifts do occur occasionally	No working allowed before 7:00 and after 17:00 (danger of wildlife encounters). Possible exception: work performed on the camp site and at office.
Secondary benefits	Provision of meals Coverage of medical cost Provision of education for 1 child per employee	Provision of meals Coverage of medical cost Provision of housing for staff outside the area

The indicators are based (ILO 2006; Lewandowski and Faaij 2006; Smeets et al. 2008; NEN 2009; GBEP 2011), see Methodology section. Sources: fieldwork, company business plans(BioShape 2009; van der Zwan 2011).

Risks arising from possible project failure loom large in the plantation model. In fact, major problems have arisen here in reality. After the bankruptcy of the Dutch BioShape Holding in April 2010, all 400 daily workers were suddenly sent home, while the contract workers were kept on for six more months, for which they were never paid. Despite the existence of national regulations to prevent these situations, no employment stability or social security was observed. A law suit has been filed in Dar es Salaam High Court trying to retrieve the unpaid salaries of over 90 contract workers (Wa Simbeye 2011d; Wa Simbeye 2011a). Failure of the processor company in the smallholder system would have more limited effects. The workers in the factory and the field team would stop receiving benefits and the smallholders would lose their market for seeds, although other seed buyers/processors may fill that gap in some regions. The impact of market loss on total household income would be minor.

In sum, both systems formally have similar labour and working conditions (although it is difficult to verify the conditions in smallholder households), but there are large differences in the set-up and the manner of implementation of the two systems, which affect how things work out on the ground. The processor firm in the smallholder system places considerable emphasis on providing employee skill training, more so than the plantation. Perhaps the latter could have organized this under the wing of its foundation, but it never reached this stage due to its bankruptcy.

Many issues discussed above - poverty, wages and employment, prices and rural development, also have a close relationship with the next topic of food security.

3.3.4 Food security

3.3.4.1 Background information

In Tanzania roughly 15% of households are considered *food insecure*, with a similar proportion considered *highly vulnerable* (McKinney 2006). Regional variability in food insecurity varies between 5% to above 50% of households (see Appendix C), but all regions suffer from high rates of stunting among children under five, indicative of chronically low nutrient intake. Thus, food security is a concern in all regions. Households relying mainly on small farming and wage labour are more likely to be food insecure than skilled labourers and traders (McKinney 2006). Chronic malnutrition is common, affecting over 30% of children under 5. Acute malnutrition, which is indicative of recent or current food shocks, is less prevalent with fewer than 6% of children affected nationwide in 2006, although 10-14% in some districts affected by drought at that time (McKinney 2006).

National food production figures show a change in food production from 2007 to 2009: millet, maize and cassava production decreased, while rice, wheat flour, beans, banana and sweet potato production increased(Ministry of Finance and Economic Affairs 2010). The reason for this decline however, is not biofuel production but ‘unfavourable weather'. The food price index increased every year since 2001, but only marginally when compared to the overall price index which also increased (Ministry of Finance and Economic Affairs 2010).

In any business model, food security may increase if household incomes increase (FAO 2010a). A study of more than 100 smallholders observed that those connected to the jatropha seeds processor reported higher levels of food security and lower incidences of food shortages compared to other smallholders, but the exact reasons could not be verified (Portale 2012). A FAO study indicates that smallholder-based biofuel systems are most effective in increasing household income (FAO 2010a). It indicates that the key factor to increase food security is to increase agricultural yields (FAO 2010a). Biofuel investments could catalyse this if they invest in increasing local communities' knowledge to achieve this. In our study, the plantation company's efforts in this respect were limited to encouragement of a school garden through its foundation. The processor was making good efforts with agricultural extension services. However, increased public spending will be also necessary to increase access to knowledge, fertilizer, improved seeds and water, and reduce input prices (FAO 2010a).

3.3.4.2 Availability and access

The area targeted for jatropha production by the plantation was not actively in use for crop production or grazing, so food availability was not directly affected. However, communities used it for hunting and possibly firewood gathering, charcoal making, medicinal plant gathering etc. If community members are paid for the reduced access caused by the plantation, then they can compensate for the loss of those resources; however there is evidence that in some cases compensation has not reached affected individuals (see section on land rights). Wage income - if stable - could compensate for the loss of traditional food access. The wages per household (especially for females) should be higher than the market value of the food produced on household plots. However, after the discontinuation of the plantation in 2010, no wages have been paid while land access is still restricted. A report by a Tanzanian NGO also indicated that the production of food in Kilwa decreased during the time that the company was active (Chachage and Baha 2010). This might be due to employees' time reduction for household food plot cultivation. The company did try to limit food price increases by buying the staple food for employees (maize and beans) in the main city Dar es Salaam.

In the smallholder hedge model, food availability and access to resources are not directly affected. A potential knowledge benefit arises from the agricultural extension work, which could help increase food crop yields. However, the timing of initial weeding requirements of jatropha can conflict with those of food crops (Mitchell 2008a). Seed harvesting seems to cause fewer conflicts on labour demand.

3.3.4.3 Stability

Sudden one-off shocks are unlikely to be caused by biofuel operations, except when they fail. However, in the plantation model seasonal (harvesting) shocks may occur, particularly as a result of the influx of seasonal job-seekers, self-employed service providers and dependents. For an estimated 10,000 employees, this could involve 50,000 people, whereas the current population of the five communities providing land to the plantation is less than 7000 (AIDEnvironment 2007; BioShape 2009). The company acknowledged that food demand will be monitored and “food supply will have to increase to service the influx”, and that it will establish “farms to service this need” [(BioShape 2009) p. 45], but nothing concrete was planned. A Strategic Impact Assessment noted that the company needs to strengthen monitoring systems. Therefore, the establishment of a large plantation in a sparsely populated region in which 30% of the population is classified as either “food insecure” or “highly vulnerable” to insecurity is likely to induce instability in supply (due to sudden large in-migration) and poses risks to food security. In contrast, schemes such as Diligent's outgrower model rely primarily on family labour and involve little, if any seasonal labour movement.

3.3.4.4 Utilization

The plantation system was meant to replace 80,000 ha of forest and woodland (see map in Appendix E), so ensuring fuel supplies for cooking would become a major issue for the nearby communities and seasonal migrants. Yet, the company business contains no plan to ensure adequate fuel supplies, so food security also could be threatened through lack of access to cooking fuel. Such threats are unlikely to arise in the smallholder production system. Smallholders were never observed to replace live fences containing fuelwood species entirely with jatropha. The processor also produced seedcake-based alternatives for charcoal and wood for use in urban areas: solid fuel briquettes, pellets and biogas from the seedcake (Van Eijck 2009; FACT Foundation 2010). In contrast, the initial plantation model foresaw 100% oil extraction in Europe, with the seedcake to be utilized as a solid fuel in European power plants (BioShape 2009). It remained unclear how the seedcake would be used if domestic processing were to occur after all, likely as fertilizer for the jatropha field.

Finally, local food security can be increased by improved (road) infrastructure, by making regions more accessible and cheapening transport to and from there (see Appendix C for major recent infrastructure improvements effected in Tanzania). However, neither company contributed to improved local infrastructure. BioShape's initial plans to upgrade Kilwa harbour were only meant for seed export (but those plans did not materialize).

In sum, food security can be affected in many ways in both business models (see Table 3-7 for a compilation of all factors discussed above), but risks are likely to be much greater in the plantation model due to the high influx of labourers. However, there are various measures that can be taken to prevent adverse effects or even improve the food security situation. For example, the management can regulate working hours so that some daytime is left for workers to cultivate their own food plots too. It can also prioritize food production on part of the plantation itself. Initial labour (weeding) constraints in a smallholder system are in any case limited to 2-3 years, but farmers should also be advised to keep prioritizing food production.

Table 3-7: Comparison of the food security impact by the two business models.

	Smallholder-based model	Plantation model
Food availability and access (production in region)	Not affected, but labour competition can arise[a]	Decreased but could be compensated by wages and compensation money. Effect on local food prices unclear[b]. Compensation for loss of resources might not reach targeted group
Food stability	No impact	Large influx of employees and job seekers might affect
Utilization	No impact	Possible loss of wood resourced is threat to cooking fuel provision
Measures to increase food security	Increase income	Increase income
	Extension services to increase food production	Revitalize harbor (not executed)
	Jatropha co-products used as energy source (biogas, solid fuel briquettes or pellets)	

[a]: Observed by Mitchell (2008a) who interviewed jatropha growers from the smallholders company, that weeding of jatropha can interfere with labour requirements of food crops. However, weeding is only required in the initial years of jatropha cultivation

[b]: Food was bought within the region (mostly meat, fish and vegetables) but the staple food (maize and beans) was obtained in Dar es Salaam in order to prevent an increase in local food prices.

3.3.5 Land rights

More land titles were issued and more village land certificates were handed out in Tanzania in 2009 compared to 2008 but there are also more disputes reported. However, most disputes involve areas close to cities like Dar es Salaam and Mwanza rather than truly rural areas, were our companies operated (Ministry of Finance and Economic Affairs 2010). See Appendix D for details about land issues.

3.3.5.1 Plantation

At the time of study, BioShape had acquired the first 34,000 ha of the planned ultimate 81,000 ha. This was previous “village land” that had been transferred into central government-owned “general land” for the purpose of enabling a foreign investor to lease it (Gordon-Maclean et al. 2008; Sulle and Nelson 2009a). However, BioShape did not acquire the lease through the official route, namely the Tanzanian Investment Centre, but rather through the “services” of employees in another ministry (Wa Simbeye 2011b). When this fact came out, it was not good for the company's reputation within Tanzania. The minister in question was later removed from office.

According to one field study involving one of the involved villages the village still had spare land left, such as settlement areas and Village Land Forest Reserves (Gordon-Maclean et al. 2008). The local communities were also satisfied with the company's approach, although they also mentioned that in one village compensation money had not been received - possibly due to a conflict between village and district council over the division of the compensation money (Gordon-Maclean et al. 2008).

The total amount of money that was paid varies in different sources from US$ 20-30 ha^{-1} or US$ 0.5-1 m for 34,000 ha (AIDEnvironment 2007; Valentino 2011). The money was paid through the district authorities, which kept part of it to allegedly support the development of social services in villages in the district (Gordon-Maclean et al. 2008). This was something that the village authorities had not counted on, and its legitimacy was questioned by them. It is also unclear whether the remaining share of the money that was destined for the village communities, has been distributed by the village councils to the actual villagers. Since BioShape went bankrupt it is also unclear whether villagers will ever regain their land rights, as there is no legal precedent of turning general land back into village land. Villagers surrounding another jatropha company that went bankrupt in Tanzania are facing the same issue (Carrington 2011).

3.3.5.2 Smallholders

In a smallholder-based model, land issues are less prominent because no land ownership transfers take place (Sulle and Nelson 2009a). In principle, farmers decide whether or not they want to plant jatropha and/or stop cultivating other crops on their own land. However, vulnerable groups can be affected. An additional use for land like this can worsen already existing pressures on the land, and can thus bring latent conflicts to the surface. Landowners for example, sometimes oppose to the planting of jatropha because they fear their tenants will then claim more permanent tenure rights (Practical Action Consulting 2009), an issue observed between the pastoralist Masaai tribe and Arusha airport authority. However, with the majority of the smallholders associated with the smallholder company no conflicts were found. Rather, a positive effect from jatropha was noted in the form of *resolution* of land conflicts. In some regions in Tanzania it was observed that farmers liked to plant jatropha as a fence because it limited conflicts with neighbours. This was also observed in Mali (Salfrais 2010). One qualification to make is that the regions in which the smallholder company is active are familiar with jatropha cultivation and the plants have been used as fences since decades. In other locations this might be different. Hence, it could take longer to learn to cultivate it, or that lives would change more significantly than in our case study.

Table 3-8 summarizes the land rights impacts from the two business models.

Table 3-8: Summary of impacts of the two companies on land rights

	Smallholder	**Plantation**
Land acquisition procurement, change in land access	No major impacts, weaker groups could have difficulties. Expanding into prior uncultivated land can be an issue. [a]	Village land transferred into general land and after this transferred to the company. Villages have lost access and legal rights to (part of) their land.[b,c]
Amount of ha land transfer	0 ha	34,500 ha[b,c]
Compensation for reduction	N.A.	around 30 $ ha^{-1} for local authorities and villagers, conflicts on commercial value and division of money[d]
Displacement of people	N.A.	13 people[e]
Transparency of the process	N.A.	Unclear, it is not clear whether stakeholders consultations have taken place, also unknown whether documentation was made available in Swahili
Potential risk in case of project failure	Low, hedgerows will not gain income but other production just continues	High, land rights are transferred to central government, no clause in contract that land is returned to villagers if company fails.[f]
Public opinion	Good, no land right changes involved. Some increased and lowered conflicts on land boundaries	Medium, foreign companies are seen as 'land grabbers' by some, but others are keen to see development in their area because they think they can profit.

[a]: When land tenure systems are weak, the rural population might experience difficulties sustaining their land access (Brittaine and Lutaladio 2010; Salfrais 2010). Furthermore, Wahl et al. (2009) observed that only a few smallholders hold official land ownership certificates in Northern Tanzania. Mitchell (2008a) indicated that more than 93% of the 74 jatropha outgrowers she interviewed perceived expanding their land, for multiple reasons, as problematic. Wahl et al. (2009) observed in the same region that 76-86 % of the households use their maximum amount of land for agricultural production, this was based on the National Sample Census of Agriculture 2002/2003.

[b]: (Gordon-Maclean et al. 2008)

[c]: (Sulle and Nelson 2009a)

[d]: The company paid around 30 $ per hectare as compensation payment, which is a total of 2.76 M$ (for 92,500ha) and of these revenues 40% went to the district government, 30% to the Village and 30% to the central government (AIDEnvironment 2007). Other sources mention other figures, such as 676,000 $ for 34,000 ha (Valentino 2011).

[e]: This is mentioned in (ActionAid 2009), however no further information was revealed.

[f]: A report by a Tanzanian NGO mentions several unsatisfied villagers, mainly after the company had stopped operations early 2010 (Chachage and Baha 2010).

It is clear that land rights are much more impacted by the plantation model than by the smallholder model. Unrelated to bioenergy production as such are the procedures to acquire land, determine its value, and ensure that villagers get adequate compensation, all of which are quite unclear.

3.3.6 GHG balance

A significant correlation was found between the NDVI values and the aboveground carbon content samples ($p < 0.001$), linear regression explained 51%. The most common vegetation type is forest (39 tC ha^{-1}) while the second most common type is open forest (11 tC ha^{-1}), see Figure 3-3.

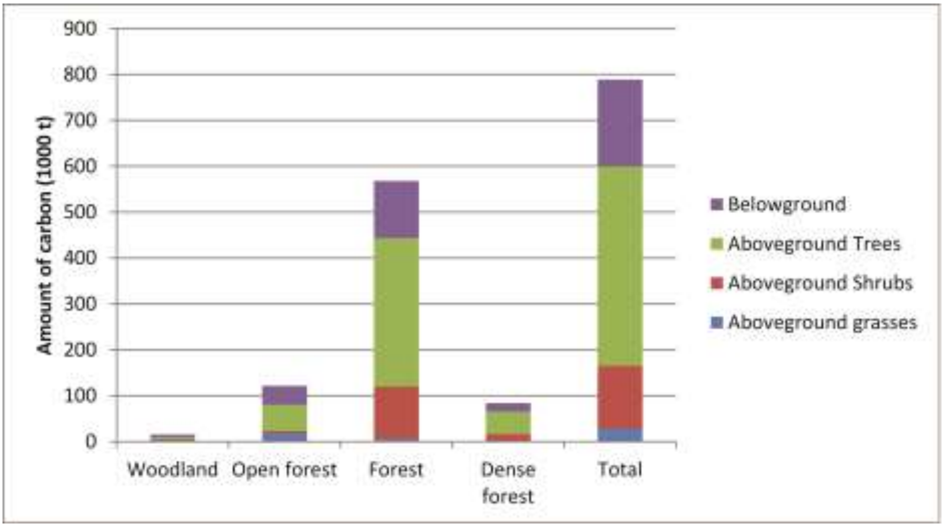


Figure 3-3: The total above- and belowground carbon (t) in the plantation area per vegetation type

Woodland (5 tC ha^{-1}) and dense forest (44 tC ha^{-1}) are less common. The total carbon stock in the area is estimated at 788,700 tC or on average 25.6 tC ha^{-1}. A carbon map of the plantation area is in Appendix E (Figure 3E-9).

The carbon content of the soil (SOC) is estimated to vary between 31 and 40 tC ha^{-1} (values derived from existing studies; details in Appendix E) (IPCC 2006; Bailis and McCarthy 2011). The carbon storage in jatropha plantations depends a lot on the pruning regime, and is estimated to be 13 tC ha^{-1} (Bailis and McCarthy 2011; Achten et al. 2012) which also tallies with the average of the range of 8-17.5 tC ha^{-1} reported by other studies (JRC 2010; Firdaus and Husni 2012). It is assumed that jatropha planted as hedgerows in the smallholders system hardly replaces other land uses.

See Table 3-9 for a comparison of all estimated emissions in the two business models.

Table 3-9: GHG balance for jatropha oil from plantation (semi manual harvesting) including upper and lower ranges and smallholders (low capacity scenario). Depreciation period is 20 years

Emission component	Smallholders[a] Emissions (kg CO2-eq ha^{-1} yr^{-1})	Plantation[b] Emissions (kg CO2-eq ha^{-1} yr^{-1})	Most positive estimate plantation emissions (kg CO2-eq $ha^{-1}yr^{-1}$)	Most negative estimate plantation emissions (kg CO2-eq ha^{-1} yr^{-1})
(A)Removal of original vegetation	0	4,533[c]	3,562[d]	4,569[e]
(B) Jatropha growth:				
Carbon stock jatropha	-1,283[f]	-2,383[g]	-3,208[h]	-1,467[i]
Δ Carbon stock soil [j]	0	-293[k]	0	-293[k]
Fertilizer use (N_2O)	142	604[l]	142[m]	604[n]
Use of agricultural machinery	0	434[o]	159[p]	488[q]
CO_2, N_2O, CH_4 indirect (fertilizer production)	178	259[r]	178[s]	1,365[t]
(B)Jatropha growth (total)	-963	-1,379	-2,729	1,283
Land use change (A+B)	-963	3,154	833	5,852
Transport	26[u]	186[v]	26[u]	186[v]
Conversion	16[w]	31[x]	16[w]	31[x]
Transport to end user	0	0		
Allocation to oil (excluding residues and co products) [%][y]	42	42	42	42
Total	-387	1416	367	2,549
Reference fossil fuel	753[z]	1448[aa]	753	1448
Emission reduction (%)	151%	2%	51%	-76%

[a]: hedgerow planting, no removal of original vegetation, no use of machinery, yield of 1 ton $ha^{-1}yr^{-1}$, depreciation period 20 yr

[b]: semi manual harvesting, yield 2 tons $ha^{-1}yr^{-1}$, depreciation period 20 yr

[c]: carbon stock 25.6 tC ha^{-1} (based on field measurements), in formula: carbon stock times CO_2/C-molar mass ratio (44/12) divided by the depreciation period is 4,693 CO_2-eq. In addition emissions from burning biomass and from the use of land clearing machines are estimated to be 96-131 and a reduction of 256 kg CO2-eq $ha^{-1}yr^{-1}$ is applied due to the decrease of forest fires and denitrification. No useful application of the vegetation is assumed.

[d]: useful application of the vegetation (furniture), therefore only 33% of the emissions are allocated to jatropha instead of 42%, here the value for 100% is depicted.

[e]: The highest range (44 kg CO_2-eq $ha^{-1}yr^{-1}$) for emissions from land clearing machines is used (Croezen 2008).

[f]:carbon stock jatropha 7 tC ha^{-1} (Struijs 2008), depreciation period 20 yr, based on hedges grown in Tanzania with 40cm spacing , same formula as [c].

[g]: carbon stock jatropha 13 tC ha^{-1} based on below ground 8-10 tC ha^{-1} (Bailis and McCarthy 2011) and the same root/shoot ratio as (Achten et al. 2012) which leads to 11-14 tC ha^{-1} averaged as 13 tC ha^{-1}, depreciation period 20 yr , same formula as [c].

[h]: carbon stock jatropha 17.5 tC ha^{-1} (JRC 2010), depreciation period 20 yr same formula as[c].

[i]: carbon stock jatropha 8 tC ha^{-1}, depreciation period 20 yr, same formula as [c]. This is an average of 7.8 tC ha^{-1} according to (Firdaus and Husni 2012) and 8.1 tC ha^{-1} according to (Hellings et al. 2012).

[j]: Ryan et al. (2011) has calculated the amount of carbon in the soil of Miombo Woodland in Mozambique, and found the values varying from 32 tC ha^{-1} to 133 tC ha^{-1}. Depending on the severeness of depletion, the study by Romijn (2010) uses a range of 49-81 tC ha^{-1} for African Miombo Woodland. The conversion from Caatinga

woodland to jatropha (rather similar to Miombo to jatropha) is estimated as 29 tC ha^{-1} by (Bailis and McCarthy 2011) while a reduction due to the clearing of the biomass was estimated as 24 tC ha^{-1} by the same study. The high values for clearing original vegetation are furthermore confirmed by (Achten et al. 2012), who estimated the effect of removal of original vegetation from tropical savannah to forest between 24-118 tC ha^{-1}.

[k]: based on BioShape estimate of 1.6tC per ha carbon storage, fruits are left on the field, same formula as [1].

[l]: 6.4 kg N_2O $ha^{-1}yr^{-1}$, N_2O is 296 times stronger than CO_2, it is assumed that fruit hulls are brought back to the plantation area

[m]: (Reinhardt et al. 2007), emission factor 0.01 kg N_2O kg N^{-1} (IPCC 2006) or 2.96 kg CO_2-eq kg N-fertiliser^{-1}, application rate (Reinhardt et al. 2008); diesel use 55-141 l ha^{-1} yr^{-1}, emissions 159-407 kg CO_2-eq ha^{-1} yr^{-1}, assumed that preparation of the land is included, emissions between 142.1-417.4 kg CO_2-eq ha^{-1}.

[n]: emission factor 0.01 kg N_2O kg N^{-1} (IPCC 2006) or 2.96 kg CO_2-eq kg N-fertiliser^{-1}, application rate; (BioShape tool); diesel use 150 l ha^{-1} yr^{-1}, emissions 453-488 kg CO_2-eq ha^{-1} yr^{-1} of which 9-44 for the preparation of land and 444 for jatropha growth, emissions between 332-604 kg CO_2-eq ha^{-1}.

[o]: use of machinery for growing jatropha 5,419 MJ ha^{-1} assuming mechanized harvesting, diesel use 150 l ha^{-1}, density of diesel is 0.85 kg l^{-1} energy content 42.5 MJ kg^{-1}. Direct and indirect CO_2 emissions from diesel use respectively: 0.07-0.01 kg CO_2-eq $ha^{-1}yr^{-1}$

[p]: (Reinhardt et al. 2008); diesel use 55-141 l ha^{-1} yr^{-1}, emissions 159-407 kg CO_2-eq ha^{-1} yr^{-1}, assumed that preparation of the land is included.

[q]: diesel use 150 l ha^{-1} yr^{-1}, emissions 453-488 kg CO_2-eq ha^{-1} yr^{-1} of which 9-44 for the preparation of land and 444 for jatropha growth.

[r]: Yield assumed 2 ton $ha^{-1}yr^{-1}$, fertilizer need N-P-K: 68-4-12 kg ha^{-1}, emission factors NPK: 3.7-0.7-0.5

[s]:(Reinhardt et al. 2007); only nitrogen fertilizers, based on nutrient removal between 48-141 kg ha^{-1}, emission per kg produced fertilizer are 3.7-6.69 kg CO_2-eq kg^{-1}fertiliser using the BioShape tool or Senternovem CO_2 tool (Bergsma et al. 2006) respectively, emissions between 178-943 kg CO_2-eq ha^{-1} yr^{-1}.

[t]: only nitrogen fertilizers, application rate at plantation is assumed 112-204 kg ha^{-1} nitrogen fertilizer, emission per kg produced fertilizer are 3.7-6.7 kg CO_2-eq kg fertiliser^{-1} using the BioShape tool or Senternovem CO_2 tool (Bergsma et al. 2006) respectively, emissions between 414-1365 kg CO_2-eq ha^{-1} yr^{-1}.

[u]: truck max 10 t within Tanzania, 450 km, seeds are processed in Tanzania, 1 ton seeds per ha, 0.08 kg CO_2-eq MJ^{-1}, truck: 0.73 MJ ton km^{-1}

[v]: 2 types of transport, first truck max 35 t within Tanzania (60km), and 15,000 t ship to Rotterdam (12,600 km), seeds are processed in Netherlands, 2 ton seeds per ha, 0.08 kg CO_2-eq MJ^{-1}, truck: 0.45 MJ ton km^{-1} ship: 0.09 MJ/ton km^{-1} (Hamelinck et al. 2008).

[w]: conversion efficiency 0.26 ton jatropha oil per hectare, crushing is 36 MJ ton seeds^{-1} (3.8 ton), pressing is 72 MJ ton seedcake^{-1} (2.8 ton) and refining 45 MJ ton oil^{-1} (1 ton), 0.16 kg CO2-eq MJ^{-1}.

[x]: conversion efficiency 0.5 ton jatropha oil per hectare, crushing is 36 MJ ton seeds^{-1} (3.8 ton), pressing is 72 MJ ton seedcake^{-1} (2.8 ton) and refining 45 MJ ton oil^{-1} (1 ton), 0.16 kg CO2-eq MJ^{-1}.

[y]: 42% allocation to the oil (energy content)

[z]: 0.26 ton oil $ha^{-1}yr^{-1}$, 36.2 GJ ton^{-1}, 0.08 kg CO_2-eq MJ^{-1}

[aa]: 0.5 ton oil $ha^{-1}yr^{-1}$, 36.2 GJ ton^{-1}, 0.08 kg CO_2-eq MJ^{-1}

The largest contributing factors to the GHG balance by far are the removal of the original vegetation (−) and the carbon sequestration in the jatropha (+). All other factors only have a marginal influence. The smallholder model generates highly favourable GHG results (151% reduction), whereas the plantation model only approximates carbon neutrality (2% reduction) over a 20-year period. If an economic allocation method instead of one based on energy would be used (in which 92% of emissions would be allocated to the SVO, instead of 42%) the emission reduction would decrease to −114% (so an increase) for the plantation model and a further reduction to more than 200% in the smallholder model. The uncertainties are very large, but the smallholder model definitely performs much better than the plantation model.

Paz and Vissers (2011) made GHG calculations for a jatropha plantation in Mozambique. Although their result (48% GHG reduction) is much more favourable than the plantation results reported here, they are mutually consistent because their estimate did not need to take account of land use change emissions, as jatropha was cultivated on an old tobacco estate. IFEU calculated GHG reductions for the same smallholder system in Tanzania and came to a saving of 444 kg CO_2-eq ha^{-1} (68% GHG reduction) (Franke et al. 2012).

3.3.7 Biodiversity

The original vegetation in the area targeted to be cleared for the plantation consists of Eastern African Coastal Forest and Eastern miombo woodland; see Appendix F (Figure 3F-10). In this area, seven tree species were found that are listed in the IUCN Red List of threatened species; see Appendix F (Table 3F-20). The plantation area is largely part of the so-called Northern Zanzibar-Inhambane coastal forest mosaic which is classified both as Critical Ecoregion and Biodiversity Hotspot. The southernmost part of the plantation is part of the Eastern miombo woodlands, which is also a Biodiversity Hotspot area. In the Northwest and Southeast, the plantation areas are bordered by forest reserves which belong to the Kilwa District Coastal Forest, which is classified as Key Biodiversity Area for its high degree of bird endemic species. The calculated Shannon and Sørensen indexes are shown in Table 3-10.

Table 3-10: Biodiversity results for the plantation model

	Nr of IUCN Red list species per class	Nr of IUCN Red list individuals per class	Shannon index	Sørensen index		
Woodland	3	12	2.18			
Open forest	2	5	2.52	0.55		
Forest	4	27	3.65	0.13	0.3	
Dense forest	4	11	3.33	0.11	0.16	0.52

From these indexes it can be concluded that ‘forest’ has the highest biodiversity value and ‘woodland’ the lowest. The floristic composition of the sampled miombo woodlands is most similar to that of ‘open forest’, while the ‘forest’ and ‘dense forest’ categories also resemble each other. The average Shannon index of 2.18 for woodlands is relatively high, compared to the average value of 1.9 for largely undisturbed miombo woodlands found in Mozambique (Williams et al. 2008). This is an indication that the woodlands investigated in this study are probably not ‘degraded’ in terms of biodiversity. For old-growth miombo woodlands in northern Zambia for example, Shannon index values of 2.17-2.19 were reported, while miombo coppice showed decreased values of 1.36-1.54 (Chidumayo 1987). Considering the large share of plant species in the Eastern miombo Woodland ecoregion of 54% which is endemic for that region, it is important to preserve this ecoregion (van der Zwan 2011). The plantation company is planning to clear ultimately 80.000 ha. No trees, except Baobabs, will be left standing. This will result in a strong decrease of local biodiversity and in a largely fragmented habitat, with expected negative impacts on the regional biodiversity, including unique ecosystems and species with restricted ranges.

There was no evidence found of threats to biodiversity if jatropha is planted in hedgerows of live fences. In Central America live fences can contribute to biodiversity, more than 160 species of birds, bats, dung beetles and butterflies were recorded, furthermore "live fences offer a means of increasing tree cover in fragmented agricultural landscapes that can be readily adopted by farmers" (Harvey et al. 2005). Windbreaks can significantly enhance the local deposition of tree and shrub seeds within the agricultural landscape by attracting seed-dispersing birds from nearby forests (Harvey 2000). However the specific value of jatropha trees in hedgerows in Tanzania would have to be further researched.

3.4 Discussion and conclusions

3.4.1 Comparison of the two business models

The key results of the comparison of the two jatropha business models are summarized in Table 3-11.These results convey that the choice of business model affects the socio-economic and environmental performance in many ways. The smallholder model scores much better on land rights, GHG balance and biodiversity and it reaches more people, whereas the plantation model creates more employment and higher (local prosperity) benefits for smaller numbers of people, and could possibly obtain higher yields. Risks of substantial negative impacts of the smallholder model are modest, whereas the plantation model could lead to decreased food security, loss of land rights and biodiversity. This could permanently affect the livelihood situation of the local population. The low GHG savings for the plantation system are due to the clearing of original vegetation; results would be much better if forest and woodland areas are avoided. A smallholder system seems to give farmers a better feeling of participation and can stimulate local entrepreneurship. On the other hand, permanent employment opportunities at a plantation model are higher, and rural development can be stimulated.

Table 3-11: Summary of the impacts on sustainability from the two business models

	Smallholder-based model		**Plantation model**	
Socio-economic areas of concern:				
1. Economic viability performance	Positive but relatively low NPV (8-18 M$ ha-1), IRR (14-18 %), PBP (12-13 y) and production	+-	Except when harvest is fully mechanized (-3 M$ ha^{-1}), the NPV is positive but relatively	+-

		costs between 1.10-1.14 $ l^{-1}		low; 15-41 M$ ha^{-1}, IRR 17-91 %, or 7% when harvest is mechanised). PBP 3->20 y, production costs 1.10-1.24 $ l^{-1})	
2.	Local prosperity	Large outreach but lower contribution per person, more non-economic impacts. 126 field jobs, 80,000-160,000 farmers 140 $ year^{-1}. Total investment 11M$, total expenses 77-130 M$, 11% of costs related to processing	+	Contribution to employment can be substantial. 10,000-35,000 jobs. Total investment 32M$, total expenses 107-125 M$, 18-20% of costs related to processing	+
3.	Labour and working conditions	Difficult to regulate at farmers level, no irregularities observed	+	Possible to regulate, no irregularities observed except in exit strategy	+
4.	Food security	Major issue in Tz; impact depends largely on household income	+	Major issue in Tz; impact depends largely on household income	+
5.	Land ownership and land rights	Low direct effects	+	Large risk of negative impacts, 34,500 ha of land transferred, compensation paid but low at 20-30 $ ha^{-1} (limited positive impact), also unclear whether money arrived at targeted group, 13 people displaced, loss of land rights after discontinuation (very negative)	--
Environmental areas of concern:					
6.	Greenhouse gas balance and carbon stock changes	Hardly any land use change effects 151% reduction if no replacement or original vegetation.	+	Previous land use is the major issue, which is strongly location specific, 2% reduction but large uncertainty due to influence of removal of original vegetation	+-
7.	Biodiversity	Increased if planted as a new hedge, but more research required	+	Very location specific, in this case strong decrease in on-site biodiversity, habitat fragmentation and decreased connectivity. 7 threatened tree species, Shannon index 2.18	-

+: positive impact, +-: neutral impact or both positive and negative, -: negative impact

The economic analysis shows similar (low) rates of profitability with current yields, and the larger upfront investment that is required by a jatropha plantation model makes such investments currently risky.

The downside of the smallholder model for the processor is that there is no secured supply even with contracted outgrowers, since honouring contracts is challenging in a developing country like Tanzania. The best approach is to pay an attractive price to farmers. This can be made possible by investing in efficient processing and adding value through selling of by-products.

Except for the financial feasibility and the environmental analysis, the comparison between these business models could also apply to other feedstocks that are used in hedges or plantations. Issues with for example land rights in Tanzania are generic to large land transfers in general in Africa. GHG balance and biodiversity calculations apply to the specific crop and location we have chosen; in a different location, the results will be different. Location specific data about yields, profits, employment requirements, poverty situation, labour availability and land use will always be required for this. Furthermore, the implementation of the models can influence the performance of the systems. Implementation aspects are project specific such as vision and strategies of management team, company values, and so on. Also the policy environment is an important factor for the implementation of potentially successful business models. Both companies that we used to represent the two models were focussed on the European market and therefore on the European sustainability regulations, e.g. RED. This might have been a reason for them to make sure that they applied a relatively sustainable business model.

3.4.2 Framework accuracy

The assessment framework is useful for early flagging of potential major areas of concern for implementation of plantations and smallholder (hedge) models, at a stage when corrective actions are still possible. However, the usefulness of indicators is partly constrained by limits on availability of data; while in certain other areas more/better indicators would be required to further operationalize the framework and obtain more accurate results. Locally practicable - not over-complex and/or overly expensive - indicators for monitoring soil, water, and air impacts are especially required. Ongoing pilot tests of the GBEP indicators and the RSB framework are expected to contribute to developing these. Furthermore, performing repeated measurements over time will provide more details on the performance of projects. Capturing wider and longer-term impacts from bioenergy projects also requires a longer-term view of the interaction with its broader development setting, taking account of factors such as policy changes, large regional development projects (e.g. infrastructure) and natural disasters such as floods or droughts. Furthermore, it will be useful to extend comparisons to other business models, especially those aiming at increasing local rural energy access, as this will assist governments and other organizations in determining which model is most or least suitable for specific locations. However, we also need to keep in mind that more extensive analysis - in whatever direction - can also reduce the framework's practicability.

3.4.3 Value of the framework for practice

One major lesson arising from the analysis is that the speed of change is a factor that requires attention. A very rapid increase in the number of people employed on a plantation as envisaged in our plantation case could cause food, fuel and water prices to rise, as local (isolated) markets have insufficient time to adjust. Both business models are expected to grow to 80,000 ha, this is a large area for cultivation of a plant that began to be grown commercially only recently. For these two reasons a gradual expansion trajectory is preferred for both models, which enables adequate time for adaptations and learning by doing. Moreover, the government should require realistic, socially acceptable exit strategies to be incorporated in the business plans, including a guarantee of re-transfer of land rights to local communities (for plantations), and cooperation agreements with other local organizations that can guarantee the market for jatropha seeds (for smallholder systems). Mandating clear communication with the local population, documented in writing in the local language for reasons of transparency, can help involve local communities and could minimize negative public perceptions and confusion. Organizing farmers into supply cooperatives groups could be a helpful model to make sure that farmers understand the value of honoring contracts and receive proper training and adequate payment in a smallholder model; it may also create a sense of social belonging and increase their bargaining power. Local governments should make sure that contracts do not repress farmers, could play a role in the establishment of farmer cooperatives and channel their own extension services through these.

The issue of food security is highly complex and our analysis cannot pretend to go beyond identifying key differences in risks and opportunities between the two models with a broad brush approach. Still, useful insights for action arise from it: in addition to boosting incomes, there are other actions that biofuel operators may take to improve food security (RSB 2011). For example, biofuel operators could provide extension services that introduce improved farming techniques, crop diversification, and/or post-harvest processing and storage. Furthermore plantations can offer flexible working hours to ensure that household subsistence food production is not compromised. Large companies using costly inputs like inorganic fertilizers could sell these on to farmers at bulk prices, or allow their earth-working equipment to be used by local farming communities. They can help to connect small farmers to micro credit facilities. The maintenance of community woodlots could help provide fuelwood, and jatropha by-products could be made available as energy sources (Wiskerke et al. 2010). Finally, contributions to infrastructural development lead to easier market access, provide wider opportunities for regional development and create public goodwill.

3.4.4 Economic viability issues

There are still large uncertainties surrounding jatropha production (especially concerning feasible yields) because the commercial use of jatropha is still new. Most large scale plantation companies assume much higher yields in their business plans than what was assumed in the 'base case' estimate of our plantation model of 1 ton seeds per ha (against BioShape's own 6 tons). Therefore, most business plans have strategically predicted much more positive results in order to attract support from financial institutions, host governments, etc., whereas we wanted to show as much as possible the actual situation with current yields, costs and prices. Currently, only farmers with low opportunity costs for family labour can profit financially from jatropha cultivation, and then only if they use a low-input regime (Van Eijck et al. 2012). Processors, who are still struggling to reach their own break-even point, cannot (as yet) afford to pay them more remunerative seed prices.

It is to be expected that, like other crops at the beginning of their commercial cultivation, efforts in jatropha breeding will lead to higher yielding, more reliable varieties which will increase financial feasibility. Several breeding research initiatives are currently ongoing such as those by JATROPT (JATROPT 2010) and QUINVITA, but results are only expected after several years. Efforts to improve harvesting efficiency (on plantations) and improve valorization of by-products could also boost profitability, such as experiments to use jatropha seedcake as an animal feed. Until results from these efforts materialize, the viability of jatropha cultivation in large plantation settings seems doubtful.

3.4.5 Inevitability of sustainability trade-offs

Business models that would generate no risks and no negative impacts on any area of concern would of course be preferred, however in practice such models do not exist. Compromises are always necessary, arising from sustainability trade-offs. In very poor regions, it is often a matter of hosting a large biofuel investor with all its pros and cons, or having no investment projects at all. This could mean a big tension between generating employment and incomes, or maintaining biodiversity. In the smallholder model, there is no less tension between ensuring adequate remuneration of farm labour on the one hand, and striving for an acceptable IRR/NPV of processing companies on the other. The value that is placed on each area of concern is location and actor-specific and is embedded in a cultural and political mindset. Hence there are no easy choices that everyone can readily agree on. A shift from the status quo will always result in winners and losers. However, the status quo is certainly also unsustainable because of severe poverty. In the light of this, sustainability certification schemes such as the RSB and NTA8080 can be viewed as extremely demanding, as they require a positive (or at least neutral) impact in all areas, whereas this can be impossible to achieve in reality.

Still, the application of our framework shows that measures can often be identified to either prevent unsustainable outcomes, or ensure that already unsustainable situations improve over time. For instance, domestic processing is very important for impacts on local prosperity, and this is something that governments can influence. Tanzania's experiences show the value of tightening export regulation and introducing some monitoring of foreign investors (Bengesi and Naiko 2009; Ishengoma 2011). Proper land use planning that can prevent future land conflicts and introducing a strong regulatory framework for land are also key government intervention areas, also identified by Habib-Mintz (2010). The Tanzanian government is discussing agro ecological zoning for better land use planning (Kiwele 2011), in the realization that the development of domestic biofuel activities - both smallholder-driven and plantation-based - should be embedded in sustainable agricultural development and land use planning.

Acknowledgements

We would like to thank Ruud van Eck and all staff from Diligent Tanzania Ltd., Pol Knops and Ina de Visser from BioShape and researchers Elisa Portale, Amanda Mitchell and Wiea van der Zwan. Furthermore we thank three anonymous reviewers who provided valuable comments. This study was partly funded by Agency NL under the DBM program, by the Global Environmental Facility (GEF) through the targeted research project “Global Assessments and Guidelines for Sustainable Liquid Biofuels Production in Developing Countries” (co-funded by UNIDO and UNEP/FAO), and by the Responsible Innovation research programme of the Netherlands Science Organisation (NWO).

3.5 Appendices to Chapter 3

3.5.1 Appendix A: Economic analysis

Plantation

The total area of 80,000 ha is assumed to be planted, in patches of 200 ha each (400 patches). Each patch is managed by a block-manager/field officer. Two harvest systems are considered for the large scale plantation:

- *Semi-manual*: Collection is performed by collection teams that work 120 days per year. The harvesting efficiency is higher than manual harvesting due to the use of machines similar to olive-tree-shakers, whereby the jatropha seeds have to be picked from the ground manually.
- *Mechanised:* Harvesting machines that make fully automated harvesting possible are developed but are not yet fully field tested (Tominaga 2009). The assumptions are derived from a harvester developed by BEI international (USA), which is currently on the market (personal communication (Newton 2009) and (Kreiger 2012).

It is assumed that the total area of 80,000 ha is gradually planted with jatropha, at a rate of around 8,000 ha per year from year 4 onwards, see Figure 3A-4. This means in year 15 all jatropha trees have matured and will produce the maximum amount of seeds. A conservative estimate of a yield of 1.1-2 t $ha^{-1}yr^{-1}$ is used, which delivers 88,000-160,000 ton dry seeds yr^{-1} from the entire plantation (Van Eijck et al. 2012). The processing efficiency is 3.8 ton of seeds required for 1 ton of oil and 2.8 ton of seedcake (Diligent 2008).

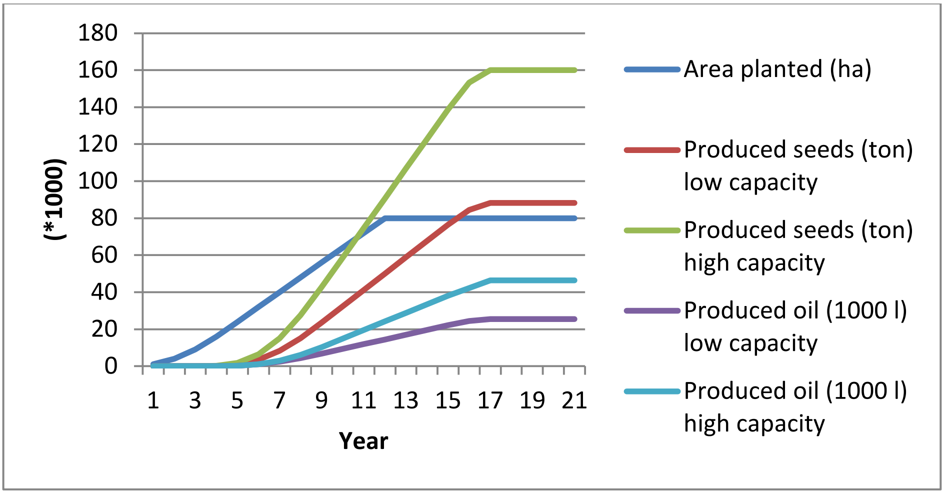


Figure 3A-4: Area under jatropha cultivation and production levels for plantation model (low represents a yield of 1.1ton ha^{-1} yr^{-1} and high represents 2 ton ha^{-1} yr^{-1})

The number of block officers increases per year, depending on the total harvest. From year 16 onwards there would be 81 field officers. See Table 3A-12 for all assumptions and the origin of the supporting data.

Smallholder system

The seeds are transported, by local transport means, to a central processing unit, with a maximum distance of 450 km between factory and farmer and an average of 300 km. A storage facility halfway serves as intermediate storage. Contracts are valid for at least 10 years and have a minimum price of 0.08 \$2009 kg^{-1} (100 TZS), this price fluctuates with the price of fossil diesel and the transport distance. Also competing seed buyers are drivers for the purchasing price. The factory gate price for example was 0.16 \$ in 2009 and the purchasing price from farmers was 0.14 \$ kg^{-1} (in 2011 the price had increased to 250 TZS or 0.17 \$2011 kg^{-1}). See Table 3A-12 for the values used in the calculations.

The analysis assumes that the number of ha planted equals the plantation model, but the growth rate is slightly slower as planting 80,000 ha by smallholders requires 80,000-160,000 farmers that have to receive extension services, which is time consuming in any location. After year 8, sufficient farmers are enlisted to plant 5,000 ha per year, and after year 14 this rate slows as the bulk of the farmers has been enlisted, see Figure 3A-5. The processing efficiency is similar to the plantation model.

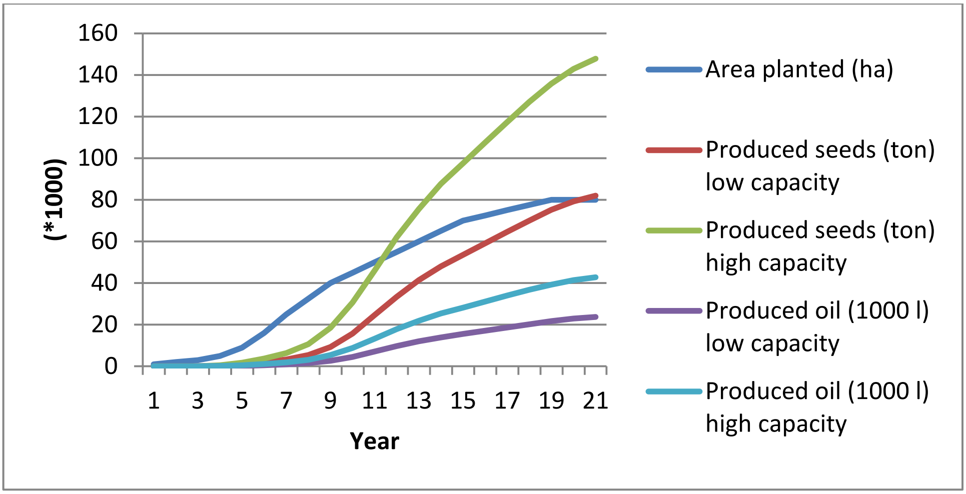


Figure 3A-5: Area under jatropha cultivation and production levels for smallholders model (low represents a yield of 1.1ton ha^{-1} yr^{-1} and high represents 2 ton ha^{-1} yr^{-1} and relates to the capacity of the processing plant)

No irrigation is assumed, therefore the production of jatropha relies on rainfall. As there are two rainy seasons in Tanzania, which means that there are two major periods of harvesting, seed collection and high production.

Table 3A-12: Key assumptions and input parameters used for the plantation and smallholders economic model

Description	Value	Unit	Source
General			
CO2 credit from sales	350,000	\$ in year 1, 5% increase yr^{-1} up to yr 15	(BioShape 2009)
SVO selling price	2,034	\$ per ton in year 0	Own estimate[a]
SVO selling price	1,017	\$ per ton in year 20	Own estimate[b] + (Diligent 2008)
Discount rate	8.2*	%	(Van Eijck et al. 2012)
Plantation model			
Cultivation			
Field officer needed to establish new plantation	500	Ha per 1 field officer	(BioShape 2009)
Field officer to monitor/support existing plantations, not yet productive	800	Ha per 1 field officer	(BioShape 2009)
Field officer to monitor/support existing plantations, productive	1000	Ha per 1 field officer	(BioShape 2009)
Yield (when the plants are mature)	1100	Kg per ha per year	(Van Eijck et al. 2012)
Labour costs for harvesting Jatropha (including all relevant costs)	0.09	\$ per kg	(BioShape 2009)
Harvesting machine			
Labour required per harvesting machine	1 2	skilled operator labourers	Own estimate

Harvest speed	1.5	ha hr^{-1}	(Newton 2009)[c]
Fuel consumption	7.5	l hr^{-1}	(Newton 2009)
Purchase price	180,000	$	(Newton 2009)
Lifetime	6	Years	Own estimate
Resale value	18,000	$	Own estimate[d]
Diesel price	1.40	$ l^{-1}	(Van Eijck et al. 2012)
Lubrication	0.21	$ l $diesel^{-1}$	(Pflueger 2005) 0.15% of fuel expenses
Wage skilled worker	2	$ $hour^{-1}$	Own estimate
Labour adjustment factor	1.1		(Pflueger 2005)
Shelter, insurance and taxes	3,600	$ yr^{-1}	(Pflueger 2005)
Repair costs	9,000	$ per year	(Pflueger 2005) 5% of purchase price
Storage and transport			
Storage/collection materials (reusable waterproof big bags)	6.60	$ per ton seeds	(BioShape 2009)
Truck capacity for seeds transport on average	7	ton seeds per truck	(BioShape 2009)
Average driving time per truckload (incl. return) (e.g. 40 km dirt roads; 80 km tarmac - vice versa)	6	hours	(BioShape 2009)
Collection days per year, in which the harvested seeds are collected from the field	120	days per year	(BioShape 2009)
Seed transport capacity per truck	1680	ton per year	(BioShape 2009)
Transport costs per truck (fuel, maintenance, insurance)	13.21	$ per hour	(BioShape 2009)
Collection staff per truck	2 1	Staff members Coordinator per 10 teams	(BioShape 2009)
Average costs per truck collection team, including bonuses, expenses and overhead	990.45	$ per month	(BioShape 2009)
Processing			
Extraction costs (electricity, maintenance and insurance)	33.02	$ per ton seeds	(BioShape 2009)
Filtering, refining and stabilisation costs (electricity, maintenance, insurance and consumables)	33.02	$ per ton oil	(BioShape 2009)
Briquetting costs (electricity, maintenance and insurance)	33.02	$ per ton press cake	(BioShape 2009)
Revenues			
Press cake selling price [e]	66.03	$ per ton	(Diligent 2008)
Multiplication rate of biodiesel sales, because of comparing the energy content of Jatropha diesel with diesel	0.9451		
Smallholders model	Value	Unit	
Purchase price collection points from farmers	0.14	$ per kg	(Van Eijck et al. 2012)
Selling price collection points to processing company	0.16	$ per kg	(Van Eijck 2009)
Daily wage unskilled worker	2	$ per day	(Van Eijck et al. 2012)
Collection costs	59.43	$ per ton seeds	(Diligent 2008)
Processing costs	36.98	$ per ton seeds	(Diligent 2008)
SVO storage and transport costs	3.68	$ per ton seeds	(Diligent 2008)
General cost increase	1	% per year	Own estimate
Selling price of press cake[e]	66.03	$ per ton	(Diligent 2008)

[*]: Real long term prime commercial discount rate (rate without inflation) in Tanzania in 2008.
[a]: based on the selling price of Jatropha SVO in Tanzania (Van Eijck 2009)
[b]: based on the price of fossil diesel
[c]: based on the figures of the BEI jatropha harvester (Newton 2009), price is equal to jatropha harvester from Oxbo international (Korthuis 2012)
[d]: 10% of purchase value
[e]: press cake sold as feeding material for industrial boilers

Other assumptions: payments to a loan guarantee fund are made and working capital increases will decrease over time and will be zero after nine years in the plantation model and after 8 years in the smallholders model. The general costs increase over time and new Jatropha plants are planted up to year 11 in the plantation model, while new Jatropha plants are planted up to year 18 in the smallholders model. There are no capacity restrictions assumed at the conversion unit in the model. Transesterification costs are around 0.28 $ l^{-1} in Tanzania as calculated by Van Eijck et al.(2012), these costs are high, mainly due to the high price of methanol in Tanzania (around 1 $$l^{-1}$) and the high-skilled labour that is required. Due to the high cost, biodiesel production is currently unviable, therefore only SVO production is assumed, see Figure 3A-6 for a breakdown of production costs.

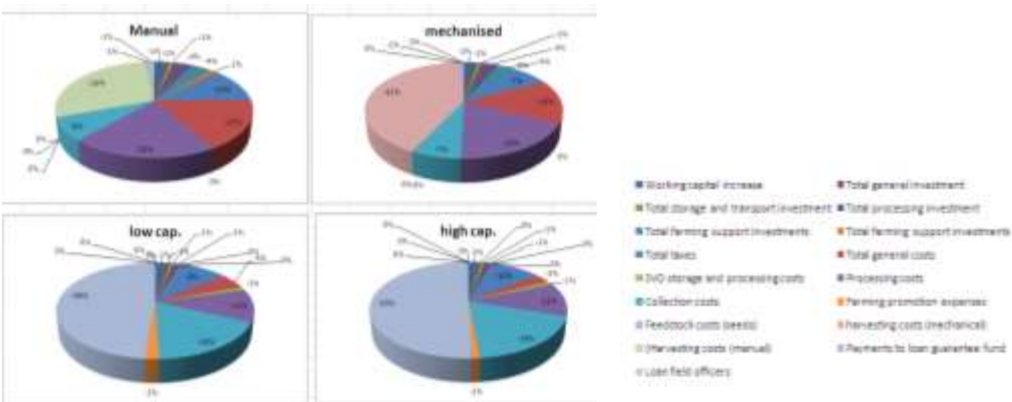


Figure 3A-6: Breakdown of production costs

3.5.2 Appendix B: Local prosperity

Table 3B-13: Background Tanzania data on local prosperity.

Background indicator	**Value for Tanzania**	**Source**
Local prosperity		
GDP	54 billion \$ 548 \$ per capita	(UNSTATS 2011)
GINI	34.6 (2000) 37.6 (2011)	(UNDP 2011)
HDI[a]	0.466	(UNDP 2011)
Population below the poverty lines	97% <2 \$ PPP (2000-'07) 68% < 1.25 \$ PPP (2000-'09)) 33% < national poverty line (2000-'09) 37% of rural population < national poverty line (2007)	(UNDP 2009) (UNDP 2011) (UNSTATS 2011)
Multi dimensional poverty index[b]	0.367 (2008)	(UNDP 2011)
Poverty gap ratio[c]	28.1 (2007)	(UNSTATS 2011)
Minimum wage	48-260 \$/month or (\$1.7-\$9.3 a day), since 2010 minimum wages changed to 49-245 $\$_{2010}$	(Association of Tanzania Employers 2010)[6]
Proportion of own-account and contributing family workers in total employment	87.7 (2006)	(UNSTATS 2011)
Possessions	low	(NBS Tanzania 2006)
Literacy rate[d]	73-77 %	(UNSTATS 2011)
Population region	Total population (2009) 42 M, Kilwa 171,000	(Ministry of Finance and Economic Affairs 2010) (NBS Tanzania 2006)
Unemployment rate in the region	in rural areas unemployment is 7.1% in Kilwa: 8.4 % (14,400 people)	(Integrated Labour Force Survey 2001)

[a]: This index combines the life expectancy index, education index and GINI index.
[b]: This index combines health, education and standard of living
[c]: Poverty gap is the mean shortfall of the total population from the poverty line (counting the non-poor as having zero shortfall), expressed as a percentage of the poverty line. This measure reflects the depth of poverty as well as its incidence.
[d]: Adults and youth

[6] 65,000-350,000 TZS (Review of minimum wage-setting for the private sector in Tanzania 2007) or : http://www.oecd.org/dataoecd/12/25/40578365.pdf

Table 3B-14: Salary scale of the two companies

	Position	Daily salary (USD_{2009})	Monthly salary (USD_{2009})
Plantation			
Level 1	Assistant director, business unit manager	27	644
Level 2	Group leader large, specialist high	15	368
Level 3	Assistant manager, group leader, small specialist	8	184
Level 4	Foreman, first craftsman	5	110
Level 5	Field supervisor	3.5	83
Daily labourers	Plantation or sawmill labourers	2.6/2.3	63/55
Smallholders			
Level 1	Management, accounts/factory/laboratory		597
Level 2	Management assistant		373
Level 3	Cashier, administration		261
Level 4	Field officers/factory supervisors		119-172
Level 5	Factory assistants		75
Daily labourers	Factory, demonstration plots	2.6	

Exchange rate: Tsh-USD 1,340. A working week consists of 5.5 days/44 hours and on average 23.9 working days per month

3.5.3 Appendix C: Food security

Generally, 53% of the road network was in good condition in Tanzania in 2009, 33% was in fair condition and 14% in poor condition, slightly worse than in 2008 (Ministry of Finance and Economic Affairs 2010). Recently the last 40 km of sand road from Dar-es-Salaam to Lindi was tarmacked. This means the region is now more accessible during the rainy season which was difficult before; also travel time has been reduced. When we conducted our fieldwork for this research, the 40 km 'rough road'still existed, and it took around 5-6 hours to reach Dar-es-Salaam from Kilwa by car (220 km). There are plans to develop the road further down South to link to Mozambique (SIDO 2011). Also, during 2008-2009 a road from Dar es Salaam through Shinyanga and Singida regions to Mwanza was finalized, reducing transport time and costs in those regions significantly. This is where the processor company sources a lot of its seed supplies.

Table 3C-15: Food security in regions of Tanzania where commercial jatropha production has been established in a large plantation or a smallholder system (McKinney 2006).

Project	Regions	Food insecurity [a]		Malnutrition (0-5 years)		Most common livelihoods in each region (vulnerable livelihoods are shown in **bold**)
		% FI	%HV	Wasting	Stunting	
Plantation	Lindi	10%	21%	8.5%	29%	Crop Farmers 22%; **Small farmers 14%**; Petty Traders 14%; Agro-Pastoralists 10%
Smallholders[b]	Singida	56%	24%	6.0%	30%	**Small Farmers 44%**; Crop Farmers 13%; Petty Traders 11%
	Manyara	24%	21%	14%	40%	**Poor income 37%**; **Small farmers 27%**
	Mwanza	21%	25%	4.4%	34%	Crop Farmers 26%; Agro-Pastoralists 13%; Petty Traders 13%
	Arusha	10%	11%	11%	24%	Agro- Pastoralists 23%; Petty Traders 20%; Crop farmers 13%; **Wage Laborers 12%**
	Shinyanga	5%	9%	3.2%	21%	Crop Farmers 54%; **Small Farmers 17%**
	Pwani	2%	12%	4.8%	33%	Crop Farmers 54%; **Small Farmers 17%**
	Mbeya	1%	3%	1.7%	37%	Crop Farmers 40%; **Small Farmers 33%**
National Average		15%	15%	5.6%	34%	Crop Farmers 24%; **Small Farmers 20%**; Petty Traders 11%

[a] As defined in (McKinney 2006). FI = Food Insecure; HV = Highly Vulnerable

[b] This shows regions where outgrowers and Jatropha farmers were active at the time of writing. Regions are ordered from the least food-secure to most food-secure based on (McKinney 2006).

3.5.4 Appendix D: Land rights

In Tanzania land is grouped into three categories (Sulle and Nelson 2009a):

1. Village Land - This land belongs in the village area and is managed by the village council (the village must be registered and have a certificate of customary right of occupation).
2. General Land - The land under the central government.
3. Reserve Land - Conservation areas such as national parks and game reserves.
   Only General Land can be given out for commercial purposes, this means Village Land first has to be converted into General Land if it is targeted for large-scale biofuels production (Sulle and Nelson 2009a).

Table 3D-16: General land development in Tanzania, source (Ministry of Finance and Economic Affairs 2010)

General land development issue	2008	2009
Number of land titles issued	13,378	26,231[a]
Number of village boundaries surveyed	690	1,101[b]
Number of villages that were given Village land certificates	498	2,624[b]
Number of villager's farms surveyed		50,961
Number of customary title deeds issued (out of surveyed farms)	2,834	40,293[c]
Number of plots surveyed and given rights of occupancy	21,962	38,700[d]
Number of farms surveyed	676	623
Number of disputes reported at land and district councils	15,422	18,961
Number of disputes resolved (out of above)	6,770	7,123[e]

[a]: increase is attributed to the increasing pace of issuing tittles due to the establishment of zonal land offices.

[b]: increase is attributed to the implementation of a pilot project of surveying villagers farms in Babati, Bariadi, Namtumbo and Manyoni districts.

[c]: increase is attributed to the implementation of a pilot project of surveying villagers farms and issuance of customary title deeds. The title deeds were used as collateral in securing loans from financial institutions and the Agriculture Input Trust Fund.

[d]: increase was reported to be a result of using modern technology and an increase of private land surveyors.

[e]: increase in absolute numbers of disputes resolution is attributed to the increase of land disputes councilors (judges) to two judges in some councils with lots of disputes such as Dar es Salaam and Mwanza.

Table 3D-17: Background Tanzania data on land rights.

Background indicator	Value for Tanzania	Source
Land rights		
Village land certificates handed out	13,000 in 2008 and 26,000 in 2009[a]	(Ministry of Finance and Economic Affairs 2010)
Number of land disputes	19,000 in 2009[a]	(Ministry of Finance and Economic Affairs 2010)
Dispute dissolving rate	44% in 2008, 38% in 2009[a]	(Ministry of Finance and Economic Affairs 2010)
Population density	40 people km^{-2} in Tanzania, 12.5 people km^{-2} in Kilwa region	(AIDEnvironment 2007; FAO 2008a)

[a]: See also **Table 3D-16.**

3.5.5 Appendix E: GHG balance and emissions from land use change

See Figure 3D-7 for the exact location of the measured plots at the plantation area. The data that is used for the environmental impact is presented in Table 3E-18. The regression analysis that shows the link between the field measurements and the NDVI values is presented in Figure 3E-8 and the carbon map of the area is presented in Figure 3E-9.

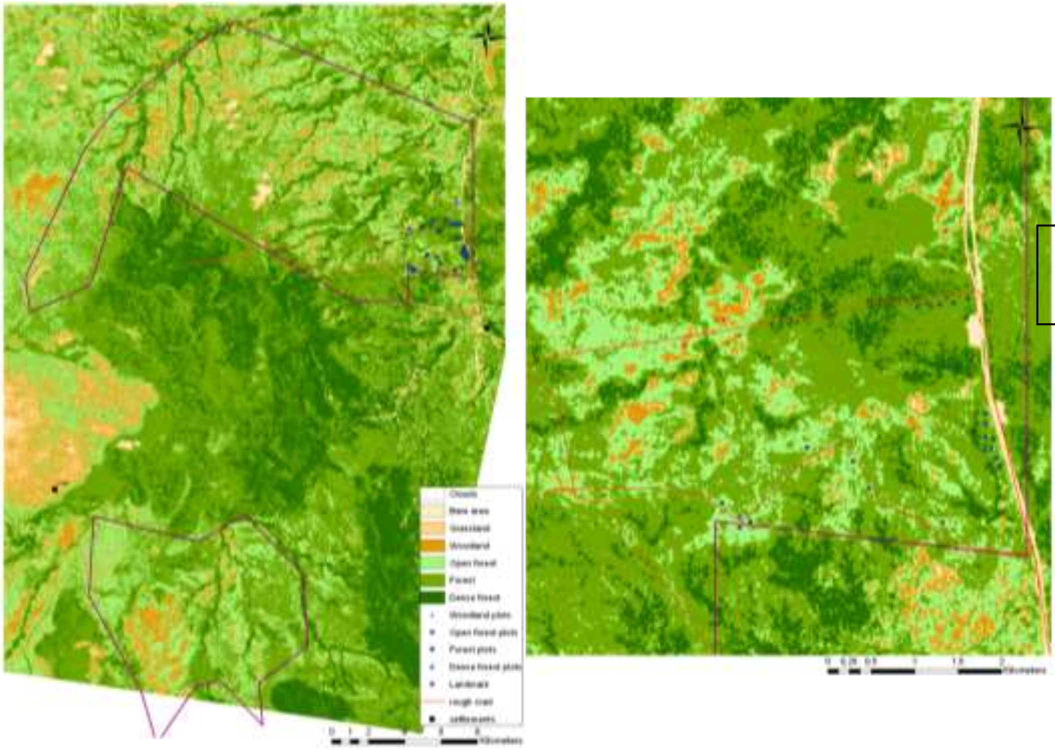


Figure 3E-7: The location of the plots for which the above ground biomass is measured

Table 3E-18: Data of the satellite image and input data for GHG calculations

		Source
	Satellite image	
ASTER Orthorectified Image	5 May 2005[a]	
Location	Path 166 and row 066 of WRS-2	
Coordinates	Upper left corner 8°38'16"S, 38°52'50"E Upper right corner 8°43'20"S, 39°27'07"E Lower left corner 9°11'43"S, 38°45'29"E Lower right corner 9°16'48"S, 39°19'50"E Scene centre 8°57'32"S, 39°06'19"E	
Resolution	15m x 15m	
Cloud cover	1 %[a]	
	GHG calculations	
Default wood density	0.56 t m^{-3} [b]	(Williams et al. 2008)
Conversion rate biomass to carbon	0.5 for shrubs and trees 0.45 for grasses	(Gifford 2000 cited by (Rahman et al. 2008)
Dead organic matter	1 t ha^{-1}	(Croezen 2008)
Below ground biomass ratio	1.6 tropical grassland	(IPCC 2006)

	0.5 woodland/savannah 0.4 shrubland 0.28-0.68 tropical dry forest	
Carbon stock Jatropha	17.5 t C ha^{-1}	(JRC 2010)
SOC soil organic carbon	34.5 t C ha^{-1}	(IPCC 2006)

[a]: Image is taken during the day, this image was chosen since it has a relatively high resolution and there were almost no clouds present which could disturb the analysis.
[b]: Density of Miombo woodlands in Mozambique

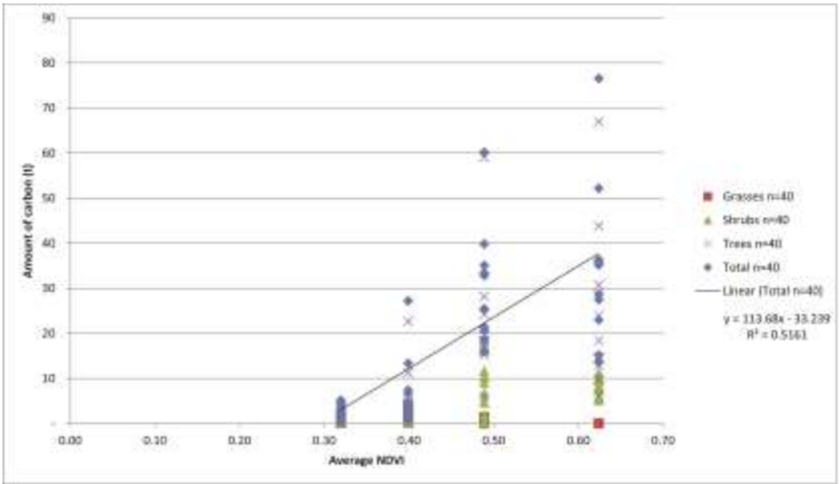


Figure 3E-8: The relation between the NDVI values and the estimated aboveground carbon (t ha^{-1}). The linear regression is for the total amount of carbon. Regression parameters: y=113,68x-33,239 r2=0.51, p=<0.001.

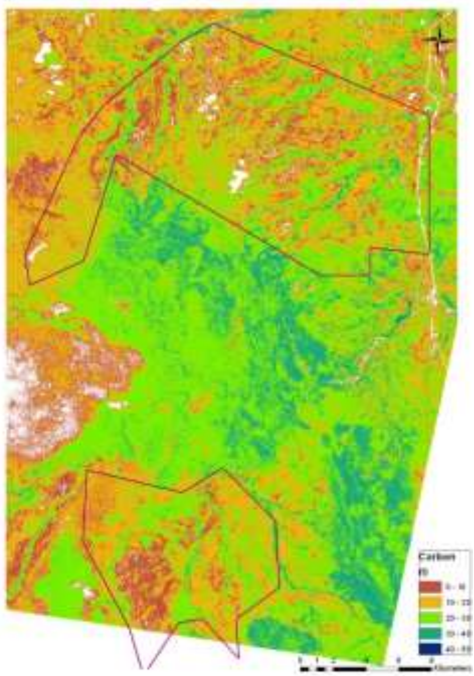


Figure 3E-9: Carbon map of the plantation area derived from NDVI values

3.5.6 Appendix F: Biodiversity

The formulas of the two indices that are used to analyse the tree and vegetation diversity of the plantation area are presented below:

- Shannon-index
  This index accounts for both the abundance and evenness for species present and is calculated using the following formula, Equation 3F-2

Equation 3F-2

$$H' = -\sum_{i=1}^{S}(p_i \ln p_i)$$

H'= Shannon's diversity index
S= total number of species in the community (richness)
P_i= proportion of *S* made up of the *i*th species

- Sorensen-index
  This index indicates the similarities between the vegetation types. This is done by dividing the number of similarities between the vegetation types (N) by the sum of number of individuals of sample A and B (S_A+S_B) in the following equation whereby a value of 0 indicates no species overlap and a value of 1 indicates that exactly the same species are found:

Equation 3F-3

$$QS = \frac{2N}{S_A + S_B}$$

QS = Sorensen index
N= number of similarities between the vegetation types
S= number of individuals of sample

Table 3F-19 shows the data and maps that have been used to analyse the impact on biodiversity at the plantation site. Figure 3F-10 and Table 3F-20 show the results of the GIS analysis; the location of the plantation in relation to the four international biodiversity maps, and the observed 'threatened' tree species in the plantation area.

Table 3F-19: Input data for assessment of biodiversity impacts

Biodiversity		
Biodiversity theme	Based on	Source
Threatened species	IUCN Red List of threatened species	(IUCN 2010)
Critical Ecoregions	GIS	(WWF 2010)
Biodiversity-Hotspots	GIS	(Conservation International 2007)
Key Biodiversity Areas	GIS	(IBAT 2008)
World Protected Areas	GIS	(WDPA 2010)

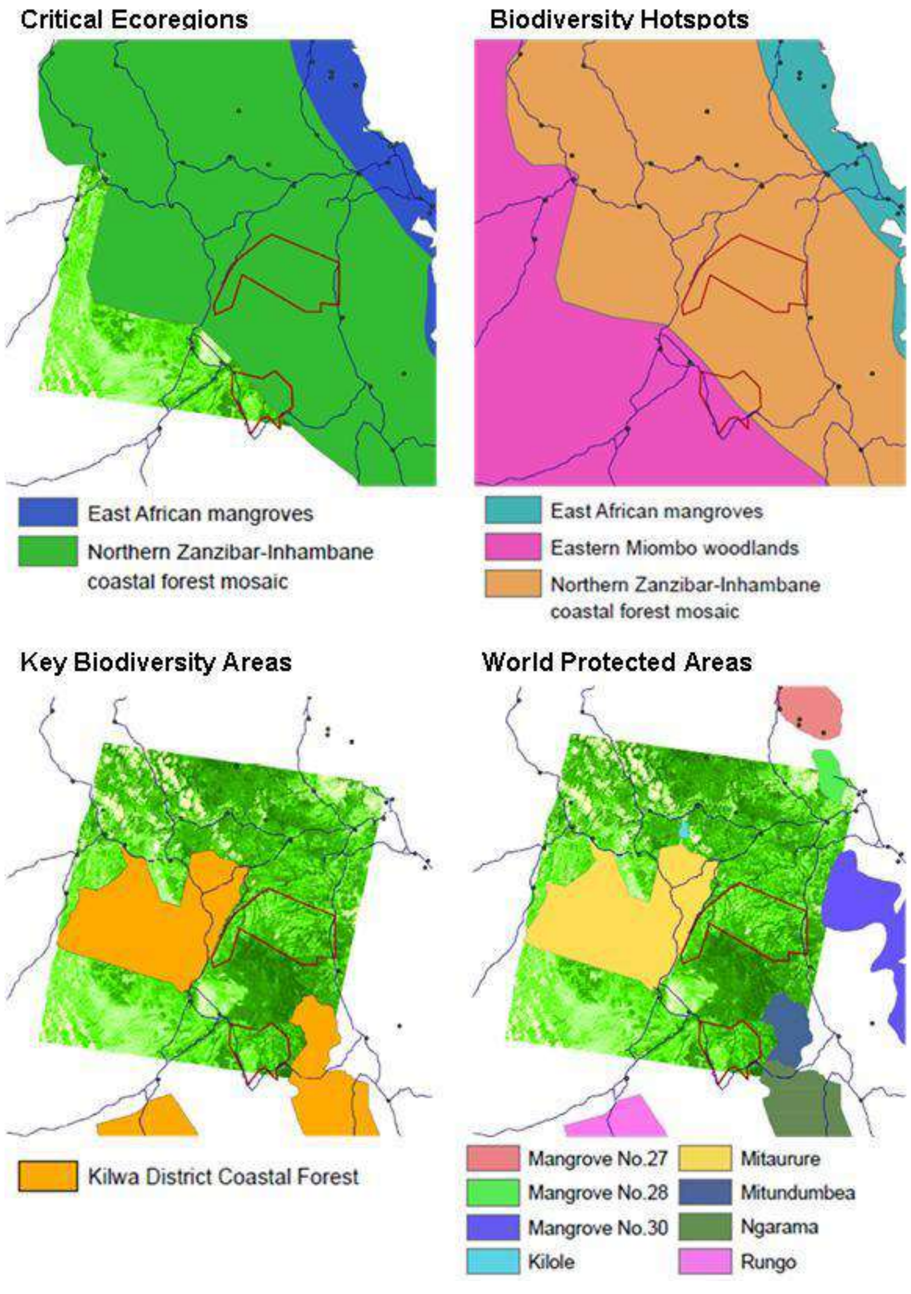


Figure 3F-10: Biodiversity hotspots, Critical Ecoregions, Key Biodiversity Areas and World Protected Areas in Kilwa district, Tanzania. The BioShape project plantations are indicated in red, the roads in blue, and different important and relevant areas in other colours.

Table 3F-20: Observed tree species, in the 40 measured plots, at the BioShape plantation area in Tanzania, listed in the IUCN Red List of threatened species

Kiswahili tree name	Latin tree name	English name	IUCN
Mkondekonde	Prunus Africana	Red stinkwood, Bitter-almond, African cherry	Vu A1cd ver 2.3 (1994)
Mfunda	Cynometra sp.		Vu B1 + 2b (c), (D2) ver 2.3 (1994)
Mtachi	Cleistanthus sp.		Several species are vulnerable in IUCN
Msante/Msande	Commiphora sp.		Several species are vulnerable in IUCN
Mpingo	Dalbergia melanoxylon	East African Blackwood	LR/ nt ver 2.3 (1994)
Mtumbati	Pterocarpus angolensis	African bloodwood	LR/ nt ver 2.3 (1994)
Mkoko	Rhizophora mucronata	Mangrove tree	LC ver 3.1 (2001)

Vu-Vulnerable, LR-lower risk, LC-least concern. Based on fieldwork in 2009 (van der Zwan 2011)

4 Current and future economic performance of first and second generation biofuels in developing countries

JANSKE van EIJCK, BOTHWELL BATIDZIRAI and ANDRÉ FAAIJ Submitted[7]

Abstract

Net present value (NPV) and total production cost calculations are made for first and second generation biofuels in 74 settings, covering 5 fuel output types, 8 feedstock types, 12 countries and 8 combinations of agricultural management systems between 2010 and 2030. Yields are assumed to increase due to better crop management and improved varieties. High NPVs (meaning profitable production) are calculated for cassava (up to 16,000 $/ha) and palm production (up to almost 7,000 $/ha). But cassava can also have a negative NPV which indicates that the project investment is not without risk. The calculated NPVs for jatropha range from -900 to 2000 $/ha, while for sugarcane and soy the NPV is always positive, (2500-5000 $/ha and 200-3000 $/ha respectively) and therefore profitable. Total production costs in 2010 are estimated to vary from 5-45 $/GJ for 1st generation feedstocks in 2010, and from around 10-35 $/GJ in 2020, compared to 20-30 $/GJ for fossil fuels. Argentina and Malaysia are the regions with the lowest production costs for biofuel (soy and palm biodiesel for 8-10 $/GJ and 8-23 $/GJ respectively), although potential for cost reduction exists in other regions. Production costs of 2nd generation biofuels are estimated to be 17-26 $/GJ in 2020 and 14-23 $/GJ in 2030. Poplar based synfuel production in Ukraine has the lowest costs (14-17 $/GJ) and rice straw based bioethanol the highest (23-26 $/GJ) - for both the short and long term. The time between investment and benefits, as well as the size of investment and the alternative commodity markets, varies with the type of feedstock. The choice of feedstock therefore depends on the local agricultural system, and the preferences and means of the local farmers. Key to the competitive production of 2nd generation fuels is the optimisation of the conversion process, which dominates overall production costs (with 35-65% of total costs). Also important is the efficient organisation of supply chain logistics, especially for the low energy density feedstocks such as wheat straw -requires densification early in the chain. Key factors in the economic analysis are: labour costs and requirements, agricultural efficiency, conversion cost and biomass yields. Acquiring accurate location specific data is essential for detailed analyses.

[7] This chapter is based on research funded by GEF UNIDO/FAO/UNEP

4.1 Introduction

Climate change is at the top of the political agenda and negotiations are ongoing in order to set an international policy framework in a post-Kyoto era, where developing countries are expected to commit towards emission reductions. Biofuels offer a large potential to displace petroleum fuels in transport and some stationary applications, with the promise to decrease global greenhouse gas (GHG) emissions. Furthermore, biofuels bring along other sustainability advantages such as energy security, rural development, postive impacts on (regional) GDP, and mitigation of local pollutant emissions (Chum et al. 2011; van der Hilst et al. 2011; Wicke et al. 2011; Franke et al. 2012; Herreras Martínez et al. 2013a). The main drivers for the deployment of biofuels are:

1. Contribution to energy security by diversifying sources, increasing the number of producing countries and a potential to 'homegrown' energy;
2. Potential to contribute to necessary GHG emission reductions by replacing fossil fuels;
3. Potential to contribute to development, with special focus on rural development, revalorization of rural areas and improving access to modern energy services.

Moreover, increasing energy prices, particularly of oil, are also stimulating the market for alternative energy sources, and bioenergy appears to be increasingly competitive in developing countries, due to suitable climate conditions and relatively low land and labour costs (Smeets et al. 2007; Wicke et al. 2011). However, increasing concerns have been expressed recently with regard to the sustainability profile of biofuels. Frequently cited issues of concern include environmental problems and social conflicts that could result from energy-food source competition, but criticisms also point to potential economic unsustainability.Various authors have analysed environmental (eg. GHG emissions by Hoefnagels et al. (2010)) and social effects in developping countries (Franke et al. 2012). From various reports it can be concluded that the results and impacts vary greatly from country to country and that some practices and technologies are more sustainable than others. The impacts of bioenergy projects in developing countries depend, among others, on the natural conditions (climate, soil), on the socio-economic setting (employment, poverty, governance) and especially on the energy crop production system that is used (crop type, low vs. intermediate or high inputs) (Dornburg et al. 2010; Schut et al. 2010b; Chum et al. 2011). However, detaild data availability is problematic for developing countries. Studies that look at economic sustainability, focus on one specific region (e.g Africa), or on one specific management type (eg. smallholders) (Mulugetta 2009; Wiskerke et al. 2010; Van Eijck et al. 2012), while this does not take into account the large variety in sustainable biofuel production options. Therefore the objectives of this study are to compile data sets for biofuel production in developing countries, and to analyse the economic performance of biofuels produced in developing countries taking large variations between crops and countries into account.

Sustainability of production in terms of financial feasibility, depends (amongst others) on the specific local context, the type of business model that is used, and the type of feedstock (Van Eijck et al. 2012). Nearly all steps within bioenergy fuel-cycles can be realised with different processes, intensity and efficiency, emissions, land use patterns, etc. and under very different social and economic circumstances. Variables are the fuel type produced, the feedstock used, the soil characteristics and climate conditions where production occurs, the type of cultivation, socio-economic conditions (e.g. price of labour and fuels, (un)employment rate, availability of land for energy crop production, ownership of land), among other factors. There is a multitude of farming and forestry systems, residue extraction or waste collection systems, downstream conversion routes, and waste treatment options as well as their respective links to auxiliary energy, as well as fuel and material inputs and associated transports.

To incorporate this broad variety of cases, a so-called setting approach has been developed whereby a variety of variables are combined into 74 different settings. The variables that are considered are; fuel output, feedstock input, geographical scope, crop management system and time frame.

The feedstocks that are selected will include the most commonly used in developing countries (e.g. sugarcane and palm oil) and some of the most promising ones (e.g. switchgrass, organic residues), including both first and second generation crops, conversion technologies and fuels. More than 99% of all currently produced biofuels are classified as “first generation” (i.e. fuels produced primarily from cereals, grains, sugar crops and oil seeds) (IEA, 2008). “Second generation” or “next generation” biofuels, on the other hand, are produced from lignocellulosic feedstocks such as agricultural and forest residues, as well as purpose-grown energy crops such as vegetative grasses and short rotation forests (SRF). Economic analyses include a detailed analysis of the viability of feedstock production (in terms of Net Present Value (NPV) and the total production costs including conversion, transport and distribution.

This chapter is structured as follows: Section 4.2 explains the methodology and the 'setting' approach, while in Section 4.3 the results of the economic analysis is provided. In Section 4.4 the results are discussed and Section 4.5 finalises with the conclusion and recommendations. Detailed input data are provided in the appendix of this Chapter.

4.2 Methodology

4.2.1 Settings

A "Setting" is a combination of fuel chains ("life-cycles") with similar typical socio-economic (e.g. ownership structure, intensity and scale of production) and environmental (geo- and biophysical, climatic) characteristics. This study considers fuel produced, time frame, final feedstock type, geographical scope and crop management system as discussed below.

Fuel output

All liquid fuels that have reasonably large market shares are considered:

• SVO (Straight Vegetable Oil)
• Biodiesel, 1st generation FAME (Fatty-acid methyl ester)
• Biodiesel, 2nd generation BTL (Biomass-to-Liquid)
• Ethanol, 1st generation
• Ethanol, 2nd generation (enzyme-enhanced lignocellulose conversion)

Other fuels such as bio-butanol, bio-methane and bio-electricity for transport, are not considered in this analysis, because of their limited current market share and experience.

Time frame

Three timeframes are included; 2010 and 2020, and for 2nd generation biofuels: 2020 and 2030. For 2020/2030 estimations took into account yield and cost developments.

Feedstock input

The selection of feedstocks that are considered for analysis reflects a representative list that applies to many geographical regions but is still manageable. The following feedstocks (with reference - between parentheses - to the liquid fuels they are converted to) were selected:

- Sugarcane (1st and 2nd generation EtOH)
- Cassava (EtOH)
- Oil palm (FAME, SVO)
- Energy grass (2nd generation EtOH, BTL)
- Soy (FAME, SVO)
- SRC: short rotation coppice (BTL, EtOH)
- Jatropha (FAME, SVO)
- Organic residues such as rice straw (2nd generation EtOH)

Some other feedstocks are worth mentioning, such as maize, rapeseed, sweet sorghum, pongamia, castor, cotton, and sunflower. Those were not selected because maize is mainly produced in the United States and rapeseed in the European Union. Furthermore the current market share of the other crops is limited, and data availability for sweet sorghum in developing countries is poor.

Geographical scope

The combinations of feedstocks and geographical coverage that have been selected are listed in Table 4-1. Often several agro-ecological zones (differences in terms of climate, landform and soils, and/or land cover) and socio-economic conditions exist in a given country. Details on the specific regions that are selected are provided in the result section and input data section in the Appendix. The selection of feedstocks and geographical areas provides a representative selection from the multitude of potential settings for developing countries.

Table 4-1: Countries and feedstock combinations included in this analysis

	Soy	Sugarcane	Oil palm	jatropha	Cassava	Energy grass	SRC	Residues
Africa								
Mali				✓				
Mozambique		✓			✓		✓[a]	
Tanzania				✓	✓			
Americas								
Argentina	✓					✓[b]		
Brazil		✓					✓[a]	
Colombia			✓					
Asia								
China								✓[e]
India				✓				
Indonesia			✓					

Malaysia			✓					
Thailand					✓			
Europe								
Ukraine							✓[c]	✓[d]

a) Eucalyptus, b) switchgrass, c) poplar, d) wheat straw, e) rice straw

Crop management system / cultivation

The management systems are described per feedstock. Three different management systems are taken into account:

Low inputs/intermediate inputs/high inputs:

The input levels influences the labour requirements for feedstock production, affecting the expenses and the yields. Input levels apply to the activities in the crop management system, from land preparation, to cultivation and, if applicable, post-harvest activities such as storing or packing (based on (Batidzirai et al. 2006; Van Eijck et al. 2012) Table 4-2 provides a detailed overview of the different activities that are included per input level. Also the typical quantities of fertiliser and pesticides use, vary, see detailed data in Appendix B.

Table 4-2: Activities that are included in the crop management system per level of inputs

	Field clearing	Filed preparation	Planting	Weed control	Pruning	Fertilisation	Pest and disease control	Irrigation	Harvesting	Post harvest activities
Low inputs	●	●	●	●					●	●
Intermediate inputs	●	●	●	●	●	●	●		●	●
High inputs	●	●	●	●●	●	●●	●●	●	●	●

•• indicates a higher level of intensity

Low level of mechanisation / high level of mechanisation / no mechanisation:

The level of mechanisation influences expenses (field clearing, field preparation, planting, weed control, fertilisation etc.) and also affect socio-economic impacts by the reduced amount of (unskilled) labour that is required. There is a 'normal' or most common level of mechanisation (referred to as 'low level') and a level of mechanisation that can be realised in the future (referred to as 'high level') including quantities per level of input, and related changes in, e.g. labour requirements, yields etc.

Tillage/no tillage:

The use of notillage or reduced tillage leads to better environmental performance through lower carbon and water footprint compared to the more conventional system of tillage. No tillage decreases soil erosion compared to repeated tillage, as there is a decrease in disturbance of the soil structure, furthermore there is an improvement of the physical and hydrological properties of the soil (van Dam et al. 2009b). The tillage system has an impact on the amount of residues that can be removed from the fields and water retention, and thus affect crop yields. Specially designed farm machinery eliminates the need for ploughing and minimizes the tillage required for planting.Also the amount of chemical fertilisers and herbicides applied depends on the type of tillage practice. The use of no-tillage is currently the most common practice in Argentina and is therefore incorporated in the settings that relate to Argentina (soy and switchgrass).

Overview

The matrix of 5 fuel types, 8 feedstock types, 12 geographical areas, 8 combinations of crop management/cultivation systems and 3 time frames would result in 11,520 different settings. The combinations were limited to a total number of 74 representative, though partially overlapping, settings for further analysis, that include key commodities and key lignocellulose crops, major production regions and spreading in management and intensity level, see Table 4-3. A detailed description of all settings is presented in Table 4A-8, in Appendix A.

Table 4-3: Selection of representative settings for analysis

Feedstock	Fuel	Time frames	Geographical areas	Crop management systems	Number of settings
Sugar cane	EtOH	2	2	2	8
	next EtOH	2	1	1	2
Palm oil	FAME	2	3	2	6
	SVO	1	1	1	1
Soy	FAME	2	1	3	6
	SVO	1	1	1	1
Jatropha	FAME	2	3	13	16
	SVO	1	1	1	1

Cassava	EtOH	2	3	3	15
Short rotation crop	next EtOH	2	2	1	6
	BTL	2	1	1	4
Energy grass	next EtOH	2	1	1	2
	BTL	2	1	1	2
Organic residues	next EtOH	2	2	1	4
Total					**74**

4.2.2 Investment Appraisal - NPV

Because costs and revenues occur at different points in time, and because the value of money changes during time, the Net Present Value (NPV) is calculated in order to enable a comparison between the different feedstocks. All future costs and revenues of feedstock production are transformed to their present values, which are then summed up and result in an overall net positive, negative or neutral result. This is done to show the profitability of the crop for the farmers, and is only performed for first generation feedstocks. For 2nd generation feedstocks, only the production costs are analysed since the future market values of the feedstocks are not known. Furthermore, part of the feedstocks for 2nd generation are based on residues whose market value is not known since residue markets are not yet developed in many countries. For example, in South Africa, it is difficult to determine the true price of residues for animal uses[8] since the residues are typically traded informally (Batidzirai et al. forthcoming). Also, there is little commercial production experience in developing countries of energy crops such as switchgrass and thus their market value is not known. The costs that are taken into account include all expenses from land preparation to harvesting of biomass, both labour and material expenses such as land rent, fertiliser, herbicides, other supplies, machinery and so on. The benefits are calculated by multiplying the yield and the market price for the fresh product. This means the NPV is calculated from a farmers perspective and not for example from the processor's perspective. The NPV is calculated using the following equation (based on (Van Eijck et al. 2012):

[8] Maize stover is used as animal fodder during winter in South Africa when the quality of pastures is poor.

Equation 4-1

$$NPV = \sum_{i=0}^{n} \frac{B_i - C_i}{(1+r)^i}$$

NPV	Net Present Value [$]
B_i	benefits in year i [$]
C_i	cost in year i [$]
r	discount rate [%]
n	lifetime of project [years]

The NPV will increase, if costs are reduced (inputs of fertilizers, labour, energy etc.) and/or if the benefits are increased by higher market prices or an increased yield. The discount rate that is used is the real discount rate, or long term lending rate subtracted by the influence of the inflation rate (see Van Eijck et al. (2012) for the formula[9]). The discount factor that is used is 8.2 based on Van Eijck et al. (2012). This rate, applies to many countries in our analysis: Tanzania, Mozambique, Mali and Thailand, and is assumed to be equal for the other regions considered. The discount rate for some countries varies slightly from this value, Colombia for example has a discount rate of , 10% (Fedepalma 2010b). Therefore in the sensitivity analysis the discount rate is varied to 6 and 15%.

In Appendix B, detailed input data including all expenses and revenues that are taken into account, is provided per feedstock. All $ are US$ 2010, and The economic lifetime of perennial plantations is assumed to be 24 years (based on van der Hilst and Faaij, 2012), and this is taken as reference for all 1st crops as well.

In general, a positive NPV indicates potential profitability. If the NPV is close to zero (no-profit no loss), then the financial viability of the project could be further researched using an extended Cost Benefit Analysis. The NPV is calculated using one default revenue value (an average) for the fresh products (raw feedstock). The feedstocks can be used for different markets (food, fuel, fodder), furthermore, market prices are volatile, and yields can vary per year. Therefore, as part of a sensitivity analysis, a range in market price values is included to analyse the robustness of the NPV. When looking at the results not only the NPV of the feedstock / project itself should be taken into consideration, also the performance

[9] example: if the inflation rate is 10% and the long term lending rate 16%, the real discount rate is 6.

compared to similar feedstocks or projects realized in the region. Depending on the outcome of the comparison it might be advisable to switch to a different feedstock or technology that is more profitable. Or, on the other hand, if opportunity costs in the region are close to zero, even low NPVs (a few hundred $/ha) could make investment worthwhile.

4.2.3 Total production cost

The different end products of the feedstocks, are given in US-$2010/GJ. The total production cost include: feedstock costs (including labour, fertilizers etc.), transport costs (from field to conversion plant), conversion costs (in $/l), if applicable transesterification or further refining costs and finally distribution to the end consumer (filling station). The final cost is calculated by dividing the total discounted costs by the total discounted yields, using the following equation (Smeets and Faaij 2010; Van Eijck et al. 2012):

Equation 4-2

$$C = \frac{\sum_{i=1}^{i_t} \left(ecc_i \sum_{y=1}^{n} \frac{f_i(y)}{(1+r)^y} \right)}{yld \sum_{y=1}^{n} \frac{f_{yld}(y)}{(1+r)^y}}$$

where

C: Cost of biomass [\$ kg^{-1} or \$ t^{-1} or \$ m^{-3}]
i_t: number of cost items with different time pattern
ecc_i: cost of energy crop cost item [\$ ha^{-1}]
n: number of years of plantation lifetime [dimensionless]
$f_i(y)$: number of times that cost item *i* is applied on the plantation in year *y* [dimensionless]
r: discount rate [%]
yld: yield of the energy crop [kg ha^{-1} yr^{-1} or t ha^{-1} yr^{-1} or m^3 ha^{-1} yr^{-1}]
$f_{yld}(y)$: binary number, harvest (1) or not (0) in year y [dimensionless]

For economic comparison of the various biofuel value chains, the following approach is used. For each part of the production chains, the annual investment and operational costs are calculated based on literature and expert advice. All costs are calculated for the reference year 2013. The total biofuel production costs (Cbiofuel ($/GJbiofuel) are calculated following Equation 4-3:

Equation 4-3

$$C_{biofuel} = \frac{\sum_i (\alpha \times I_i + O\&M_i + F_{ci} + T_{ci})}{Biofuel\ production}$$

Where: α is the annuity factor, I_i investment costs for supply chain stage *i* ($), $O\&M_i$ - operation and maintenance costs for supply chain stage *i* ($), F_{ci} - feedstock production costs ($), T_{ci} - transportation costs for supply chain stage *i* ($), Biofuel production (GJ/yr).

The annuity factor is calculated with Equation 4-4:

Equation 4-4

$$\alpha = \frac{r}{1-(1+r)^{-equipment\ lifetime}}$$

Where *r* is the interest rate (assumed to be 8%).

For second generation biofuels, the fuel conversion stages are especially capital intensive. It is also important to take note of the relevant equipment specific cost factors (lifetime, interest rate, etc.) and different cost type information (capital-related and installation, consumption-related and operation related). As second generation technologies are not yet mature, it is necessary to incorporate time dependent technological learning and scaling up effects in the economic analysis to make future projections.

4.2.4 Data collection

The calculations are based as much as possible on specific country level data such as wage rates, input costs, yield etc. Information on yield is based on literature sources and expert views and is verified by several local country partners[10]. The

[10] The local country partners are: Scientific Engineering Centre Biomass (SEC Biomass) in Ukraine, the national institute of agricultural technology (INTA) in Argentina and the agronomic research institute

amount of labour that is required per feedstock has been kept constant for the different geographical regions and is based on expert agronomic knowledge and selected literature that include sufficient detail (the soy calculations in Argentina e.g. are based on (van Dam et al. 2009a). The local country partners also assisted in data collection. Very detailed data on palm production by smallholders in Sumatra Indonesia was obtained through another project; the Global Biopact project in which different smallholders were interviewed and many literature sources were combined (Global Biopact 2011). The data has also partly been collected and verified by fieldwork in Mozambique (in 2010 and 2012), Tanzania (in 2006-2009, 2011) and Mali (in 2011).

The complete input data sets used in the calculations are provided in Appendix B and C.

4.3 Results

4.3.1 Economic performance of 1st generation biofuels

Soy

All 7 settings that concern soy are situated in Argentina, a country that has a lot of experience with soy cultivation. Over the last decades, soybean cultivation has grown substantially to a production of more than 53 million tons in 2010 (INTA 2011b). The main product of the cultivation of soy is animal feed while the oil that is obtained from processing is considered a by-product. Therefore, the cost of feedstock production is only allocated to soy biodiesel by 20% (by mass), but we also included price allocation (36%) to show the difference. Soy cultivation in Argentina typically takes place on large scale plantations with high rates of mechanisation. The management systems that are varied are the rate of mechanisation and the practice of tillage. Furthermore smallholders and plantations are incorporated as well as two timeframes: 2010 and 2020.

(IIAM) in Mozambique. Furthermore we cooperated with the company Cenipalma in Colombia and Prof. Gheewala from the university of Bangkok, Thailand.

Soy yields have increased on average with more than 50% since 1970, although there are large differences between the provinces (INTA 2011a)[11]. Increased yields are explained by a conjunction of factors including: agronomic, genetic, farm machinery and general management. There are good perspectives for this tendency to continue in the near future. Soybean BTRR2 specifically developed for the southern hemisphere could generate an increase between 10 and 15% in yields (INTA 2011a). We have increased the yields for 2020 but up to a maximum of 5 tons/ha, See

Table **4B-9** in the appendix for the yields used in the calculations, they are based on specific provinces in Argentina and are also discussed below.

Prices for inputs and soy beans change over time. The production costs of soy have increased since 2002, but dropped between 1991 and 2002, current costs are at a similar level as 1991, Therefore the same prices for inputs in 2010 and 2020 were used. Wages are expected to increase from 3.18 $/hr in 2010 to 8.29 $/hr in 2020.

Transport distances vary greatly, since Argentina is a large country. For setting 1 and 2 an average of 400 km between field and conversion plant is taken, based on the production regions described above (INTA 2011b). The transport costs are 0.06 $/ton km (van Dam et al. 2009b). The revenues are based on the market price for soy beans of 169 $/ton (INTA 2011a). This price can vary; the lowest price is 152 and the average price between 2005 and 2010 is 327 $/ha. This last price is based on international prices and while Argentina has an export tax on soybeans, internal prices are 24% lower than international prices which leads to 246 $/ton which is used as upper range (INTA 2011b) (INTA 2011a; Indexmundi 2013). Prices have increased since 1980 so it is unlikely that the default value of 169 $/ha will decrease. See

Table **4B-9** in the Appendix with all other input data per setting.

Figure 4-1 shows the breakdown of agricultural inputs and the calculated NPV of soy production in the selected settings. Setting 1,2 and 5 are located South of Cordoba (rio Cuarto), setting 3 and 6 in Pergamino and Pehuaio (North and West of Buenos Aires) and setting 4 and 7 South of Sante Fe.

[11] E.g. Cordoba reached an average yield gain of around 300% in the last 10 years whereas Corrientes and La Pampa reached an average yield gain of around 60% in the same period.

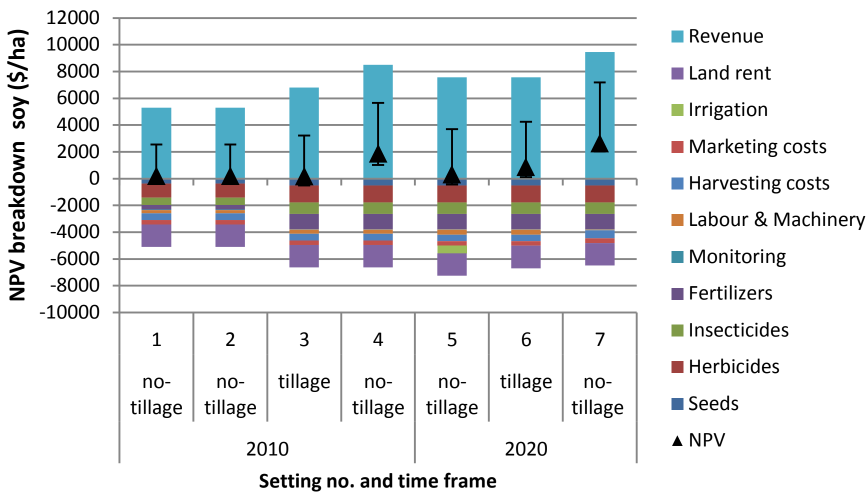


Figure 4-1: Costs, revenues and NPV breakdown for soy production in setting 1-7 (all Argentina), setting 1 includes only SVO production, setting 1 and 2 have low mechanisation rates, setting 5 includes irrigation. NPV is calculated using a market price for soybeans of 169 $/ton with a range of 152-246 $/ton.

In setting 1 and 2 only the endproduct (SVO and biodiesel) is different, the feedstock production costs are therefore equal. A main difference between the settings, related to differences in management (tillage) and location, is the yield which is 2.8 t/ha/yr in setting 1 and 2, 3.6 ton/ha/yr in setting 3 and 4.5 ton/ha/yr in setting 4. In the 2020 settings the yield is 4 and 5 ton/ha/yr for setting 5+6 and 7 respectively. Setting 5 includes irrigation which is why costs are higher. The NPV is positive in all cases, quite low in setting 1-3 (around 200 $/ha) and setting 5 (around 300 $/ha) and high in setting 4 and 7 (2000/3000 $/ha over the 24 years). However, soy biodiesel is only a by-product and agricultural producers receive most benefits from selling soy meal. Furthermore, the default NPV value is quite low considering the upper range using a market value of 246 $/ton soybeans which leads to very high NPVs of 2,500-7,000 $/ha/lifetime, and the fact that market prices for soybeans have risen over the past decade (INTA 2011a). On the other hand, large investments are required to purchase machinery for (no-tillage) cultivation, machinery costs are included, but the investment needs to be made upfront. Figure 4-1 furthermore shows that land rent is a relatively important contributor (25-33%), but also herbicides (≈20%) and insecticides (≈13%) are significant cost factors. The value of land rent that is used in the calculations is 150 $/ha/yr. This value is quite low, compared to other sources that mention prices of 200 $/ha/yr (INTA 2011b) or even higher (commercial) rates of almost 520 $/ha/yr. This would reduce the NPV in all settings to negative values (-3700 to -900 $/ha). The highest NPV is obtained in setting 7 (>2,600 $/ha), a high yield in combination with no tillage which saves labour and machinery costs (but increases herbicides costs). In Figure 4-2 the total production costs of soy biodiesel are provided.

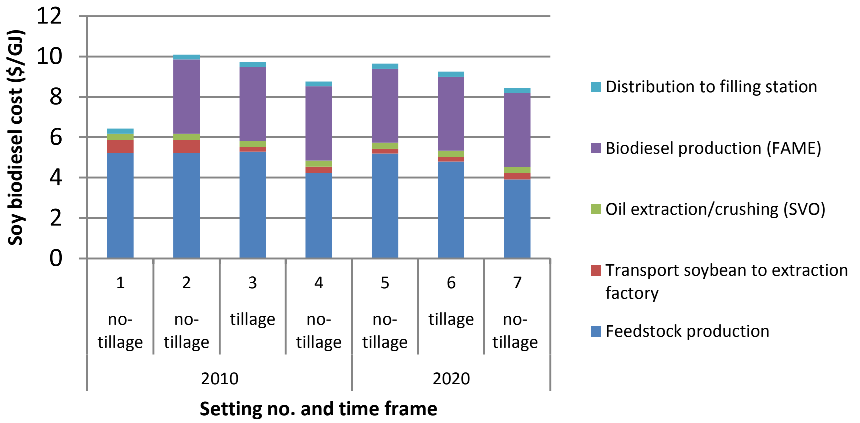


Figure 4-2: Soy biodiesel production costs for setting 1-7, all in Argentina, setting 1 includes only SVO production, setting 1 and 2 have low mechanisation rates, setting 5 includes irrigation.

The price per GJ for soy biodiesel in Argentina is relatively low, of the feedstock costs only 20% (by mass) is allocated to soy biodiesel since the main use is animal feed. If allocation is done by price (36% allocated to biodiesel) than total costs are between 12-15 $/GJ (214 $/ton for meal and 580 $/ton biodiesel (van Dam et al. 2009b) and (Indexmundi 2013). The lowest costs are obtained in setting 4 and 7, both settings with no tillage. The feedstock costs contribute more than 45% to the total costs. Biodiesel processing is the second largest component that contributes more than 40% to overall costs. The distance from field to factory, which is relatively large in setting 1 and 2, has a limited effect on the overall price, partly because transport is efficient in Argentina.

Sugarcane

The settings that relate to sugarcane are located in Brazil and Mozambique. Both countries currently produce sugarcane and sugar, but only Brazil produces ethanol. In Brazil two production systems exist; large scale plantations and outgrowers who deliver to a central processing unit. The latter is used in our calculations. The production system is placed in North East Brazil (NE), a region which has higher production costs compared to the Central South region of Brazil (CS) (where sugarcane ethanol prices are globally the most competitive), but there is also quite a lot of room for improvement. Cultivation practices have not changed much in the last decade and are not optimal. Mechanised harvest is not practised at a very large scale in the NE, but policies in Brazil require a gradual implementation, which will potentially drive other improvements. Furthermore the NE has the advantage of having several large harbours that are relatively close to the production facilities.

Both production systems also exist in Mozambique. Outgrowers often obtain almost all inputs from the central processing mill, while their only input is labour. There is a large difference between very suitable soils and less suitable soils. Xhinavane is a production region close to Maputo that has been selected for irrigated production, while the Dombo region (more in the Central region) with more suitable soils is selected for non-irrigated production. Sugarcane is cultivated in 5-yrs ratoon cultivation, the crop is planted in year 0, harvested every subsequent year and is replanted in year 6.

Two settings (10 and 15) consider both 1st and 2nd generation ethanol, ethanol produced from the juice (1st generation) and from the bagasse (2nd generation). Every ton of bagasse produces 88.3 l ethanol (CGEE 2009).

The yield for the NE is based on (Herreras Martínez et al. 2013a) and is 60 ton cane/ha/yr for non-irrigated cane and 90 ton ha/yr for irrigated cane. The yields in Mozambique (76 t/ha/yr non-irrigated and 100 t/ha/yr irrigated) are based on (De Vries et al. 2012) and (van der Hilst and Faaij 2012). The higher yields in Mozambique are explained by the high climate suitability of Mozambique for sugarcane. Per ratoon year the yield is expected to decrease to respectively 96, 92, 88, 83 and 79% of the maximum yield. Yields are projected to increase with 5% in 2020 compared to 2010.

Transport costs in Mozambique are quite high; 0.096 $/ton km, for Beira region, while for Brazil they are 0.06 $/ton km (CEPAGRI et al. 2011). Land rent in Mozambique is assumed to be 22 $/ha/yr. Depending on the type of land (bare land, agricultural etc.) this price can vary, for example agricultural land that is leased from the Government has only a tax fee of around 0.5 \$/ha/yr (MZM 15/ha/yr) (Investment Promotion Center 2009). See Table 4B-10 in the Appendix with all input data.

The market value for sugarcane that is included as default value is 35 \$/ton, based on the actual price paid in a sugarmill in Mozambique (Jelsma et al. 2010). Cane prices fluctuate, an important aspect is the quality of the cane (the sugar content). In 2005-2010 sugarcane prices ranged from 24-38 \$/ton in South Africa (a market very close to Mozambique), but from 15 \$/ton in Mozambique which is used to show the range in NPV (SASA 2013). See Figure 4-3 for the results of the NPV calculations for sugarcane production in Mozambique (setting 11-17).

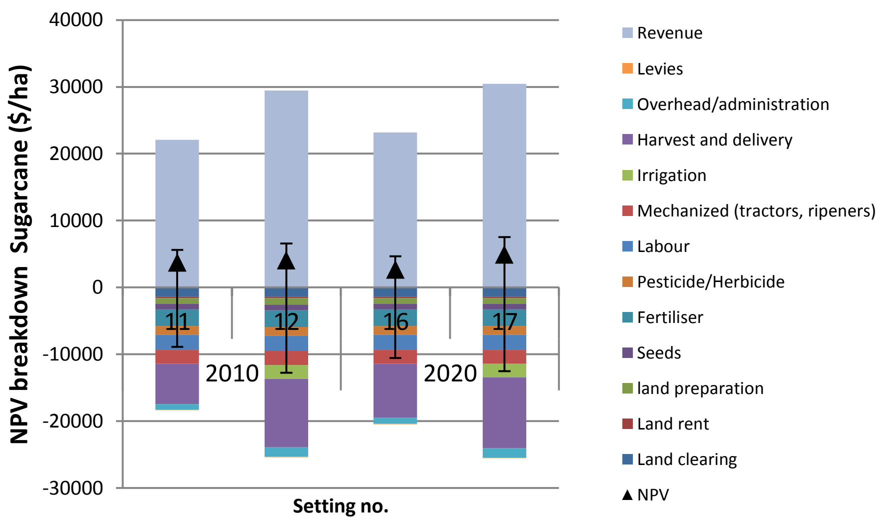


Figure 4-3: Costs, revenues and NPV per ha for sugarcane in Mozambique, settings 11 (no irrigation), 12 (irrigation), 16 (no irrigation), 17 (irrigation). Market price range used for NPV 15-38 \$/ton cane, default value is 35 \$/ton.

All NPVs in the settings for sugarcane production in Mozambique are positive, varying from 2,700-5,000 \$/ha. Note that in setting 12 and 17, it is assumed that the instalment costs for irrigation are accounted for by the central producer; the outgrower has to account for the labour that is associated with irrigation. Because of the higher yield in these settings the revenue is also higher which leads to a higher NPV. The NPV is negative for the settings if the low market value of 24 \$/ton is used. Although the price paid in 2010 was 35 $, the market prices for sugarcane fluctuate with the global sugar prices and therefore are very volatile. Furthermore, The Mozambican farmers association is weak which leads to low prices (Dias 2013). The analysis shows that the NPV is very sensitive towards price changes on the other hand producers can choose the highest price (sugar or ethanol). Harvest and delivery accounts for the largest costs (33-42%), also fertilisers, labour and mechanic equipment such as tractors and ripeners are large cost factors (8-13%). For setting 8-10 and 13-15 (Brazil) the agricultural breakdown is based on detailed calculations by (Herreras Martínez et al. 2013a).

In Figure 4-4 the total production costs are provided for all settings that relate to sugarcane (8-17).

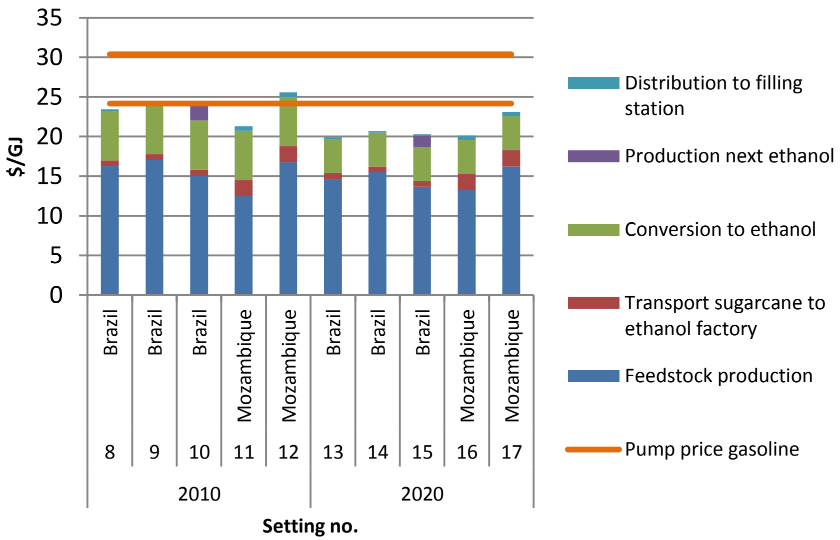


Figure 4-4: Sugarcane ethanol production costs per GJ in selected settings (8-17) (max pump price of gasoline is in Sao Paulo based on (van den Wall Bake et al. 2009), min pump price is the price of petrol in Mozambique in 2009 excluding taxes, ethanol energy content 26.4 MJ/l), settings that include irrigation are: 9,10,12,14,15,17 the other settings do not include irrigation

Sugarcane ethanol (incl. 2nd generation next ethanol) can be produced for 21-26 $/GJ in 2010 and 20-23 $/GJ in 2020 in our study. The total production costs of sugarcane ethanol are close to being competitive to its fossil alternative. This is especially the case in 2020 (settings 13-17, 20-23 $/GJ), where conversion costs are expected to be lower and yields increase. In the IPCC cost estimate for sugarcane ethanol from Brazil the sale of electricity has been included which leads to an even lower estimate of 15 $/GJ. The difference in production costs between Brazil and Mozambique are marginal, this is partly due to the high suitability of Mozambique for sugarcane and hence high yields. The transport expenses on the other hand are higher in Mozambique than in Brazil, in Brazil the sugarcane plantation in the North East are quite well connected to the harbour.

Palm

The palm oil settings that are selected, refer to production in Colombia, Indonesia and Malaysia. Malaysia is the largest exporter of palm oil and is considered to operate on a best-practice base. Colombia currently has >400,000 ha of oil palm plantations and is the worlds' fifth producer (Fedepalma 2010a). For this cost calculation section we have added a setting for palm oil production 2020 in Colombia, setting 21b.

For Indonesia the setting is located in Jambi (Harapan Makmur village) on Sumatra. Outgrowers are mainly small-scale farmers, who on average own a 2 ha farm. They obtain a relatively low yield, which appears to result from a range of factors related to sub-optimal management practices. Farmers farm their own land using family labour. Fertiliser application, the largest cost component of farmers' operating costs, is variable. Farmers currently apply a mix of inorganic fertilizers (Global Biopact 2011).

In Colombia production systems are present with small, medium and large scale oil palm growers. Especially for outgrowers, improvements in yield and the amount of hectares planted are expected to increase in the future. Cost data is derived from CENIPALMA (Investigación e Innovación Tecnológica en Palma de Aceite) and (Fedepalma 2010b). Data from Malaysia is obtained from (Ismail et al. 2003). For Colombia and Malaysia only discounted total input data was available, therefore no NPV analysis is included. All input data can be found in Table 4B-11 in the appendix.

In Figure 4-5 the NPV is shown for palm production by smallholders in Indonesia (setting 18). Yield is expressed in Fresh Fruit Bunches (FFB), it is estimated that Indonesia (16 ton FFB/ha/yr) reaches the yield level of Malaysia (19 ton FFB/ha/yr) by 2020. This is relatively conservative since a case study plantation in Malaysia, analysed by Wicke et al. (2008), yielded 25 ton FFB/ha/yr. Better genetic varieties can increase yields. Also for Colombia the expectation is that yield levels will reach Malaysia. Although Bud rot disease can seriously affect yields and has done so in

Colombia, hybrid materials have been developed but it takes some time before they are in production (Fedepalma 2010a). The benefits are based on the market value for FFB of 120 $/ton, which is based on the lower price of FFBs for smallholders in North Sumatra (between 0.12 and 0.18 $/kg). Wages are 3 $/day and farmers have to pay for transport of their FBB at a rate of around 2.2 $/kg/km (Global Biopact 2011). The price determination varies every month and is also based on the oil content in the FFBs(Maryadi et al. 2004). The marketprice is varied from 87-180 $/ton to show the sensitivity of FFB production (Maryadi et al. 2004; Global Biopact 2011).

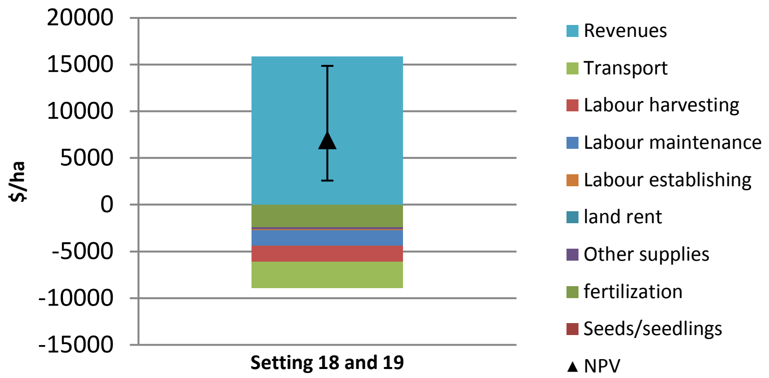
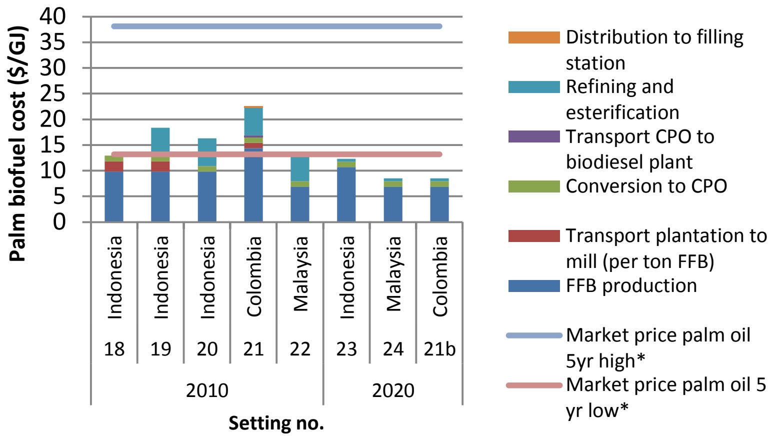


Figure 4-5: Costs, revenues and NPV breakdown (over 24 years) for palm oil in Indonesia, setting 18 (smallholders, SVO) and 19 (smallholders, FAME), NPV is calculated using default market price for FFB of 120 and a range of 87-180 $/ton.

The major cost item for total inputs in the settings for smallholders is labour (39%) followed by fertiliser (27%). Especially labour that is required for harvesting is a large cost factor. The NPV for Indonesian farmers is high (6,900 $/ha). This is due to relatively low costs for land rent (annual land tax) in Sumatra (2 $/ha/yr), the short distance between farmers and processing factory (7km), and the long yearly returns of palm. Nevertheless the cashflow is only positive from around year 4 onwards, which means farmers have to be able to make such investment up front. Smallholders also have to pay for transport expenses to the mill which is included in the calculations. Fresh Fruit Bunch (FFB) prices are volatile and since they have to be processed within a short time frame (2 days), farmers often do not have a choice but to sell them for a (set) price to the mill. The NPV using the lower market price of 87 $/ton is 2,500 $/ha/lifetime which is still profitable. The agricultural breakdown for setting 21 (Colombia) is based on (Fedepalma 2010b), and for

Malaysia based on (Ismail et al. 2003) and (Malaysian Palm Oil Board 2010), more data is needed to calculate specific NPVs. Figure 4-6 shows the total feedstock production costs and transport and processing costs for all settings related to palm oil (18-24).



*: Source for market price palm oil: (Indexmundi 2013), based on 2008-2013, the highest price was 38 US$/GJ (1250 $/ton) (feb 2011) and the lowest 13 $/GJ (433 $/ton) (nov. 2008).

Figure 4-6: Cost of Palm oil production (Crude Palm Oil (CPO) and biodiesel) in Indonesia, Colombia and Malaysia; energy content 36.92 MJ/l (Yáñez Angarita et al. 2009), Setting 18, 19, 21, 21b are based on smallholders, the remaining settings on plantations, setting 18,19 have low inputs, setting 21, 21b intermediate inputs and setting 20, 22, 23, 24 have high inputs.

Palm oil can be produced between 12-22 $/GJ in 2010 and between 8.5-12 $/GJ in 2020 in our study. Palm biodiesel can be produced at very low costs in Malaysia (≈13 $/GJ), which is lower than the IPCC estimate of 26 $/GJ but falls within the range they provide of 10-12 $/GJ based on (Milbrandt and Overend 2008) in (Chum et al. 2011). Currently the cost of producing palm biodiesel is relatively high in Colombia (22 $/GJ), but it is expected that Colombia can produce for similar low costs as Malaysia, if yields can be increased. This situation is included in setting 21b in Figure 4-6. Production on a plantation (setting 20) is possible at lower costs than production with smallholders (setting 18 and 19). In 2020 (setting 23,24), palm biodiesel can be produced at very competitive prices due to lower refining and esterification costs (9-12 $/GJ).

Jatropha

Three countries are included: Tanzania, Mali and India as well as three different management settings: low inputs, intermediate inputs and high inputs. A production system with smallholders and a plantation is also considered. The difference between smallholders and plantation farming is explained in (Van Eijck et al. 2013). Jatropha seeds are harvested from year 2-24, harvest periods in Tanzania are end of November (depending on the rainy period) and July-august. In India the harvest period is July-August and October-November in Karnataka (Estrin 2009). All three countries produce jatropha, however commercial experiences are limited. The amount of oil produced is relatively low, so therefore most cost data is derived from a small-medium sized extraction plant. Large investments have been made in Jatropha research so efficiency improvements are expected. On the other hand some large scale operations halted their activities because of disappointing results and the lack of financial resources (Van Eijck et al. 2014).

The cost factors are different for smallholders and a plantation system. A difference between the countries is that for Tanzania it is assumed that farmers have to pay for packaging, 0.45 $ per bag of 60 kg, these expenses are not accounted for in Mali and India. Bags are also often re-used.

The plantation setting is situated in Tanzania, the low input setting (no 27) represents a plantation based with manual labour, while the intermediate input setting (26) represents mechanised harvesting, see (Van Eijck et al. 2013). In the 2020 settings, the parameters for the mechanised harvester are changed, the price is decreased by 60% (from 180,000 $ per harvester to 60,000 $) and the harvesting speed is increased from 1.5 ha/hour to 3 ha/hour. For both production systems the costs are linked to the yield. Wage rates are relatively low in the countries, and only low skilled labour is required for cultivation. For all three regions the labour requirements have been kept constant, total labour requirements for jatropha depend on harvest and vary between 30-120 days/ha/year.

Jatropha is a perennial crop with a productive lifetime of >30 years. For this study, an economic lifetime of 24 years has been used. The plant matures in 6 years' time; the first year 0% of the mature yield is expected. In the second year 10% of the yield is expected and 25%, 40% and 80% in the subsequent years until year 6. Furthermore, for 2020 the yields are expected to increase by 15% considering large efforts in Jatropha breeding programs (Hawkings and Chen 2011).

The price for jatropha seeds that is paid to farmers is based on actual prices paid in the countries; 0.14 $/kg in Tanzania, 0.11 in Mali and 0.19 in India (Estrin 2009;

Simpson and Peer 2009; Van Eijck et al. 2012). Van Eijck et al. (2012) have made an extensive analysis of market prices for jatropha seeds (no other commercial markets for the seeds other than a very small share for the soap market exist). In the NPV calculations a range of 0.09-0.20 $/kg for all countries is used to show the sensitivity.

Since Jatropha production has not reached commercial levels, costs of conversion to SVO and biodiesel are relatively high; 0.20 $/l and 0.28 $/l respectively (Van Eijck et al. 2012). In India there is a well-established oilseed sector, therefore the conversion costs to SVO are lower (0.14 $/l (Estrin 2009). Conversion and transesterification costs for 2020 (0.02 $/l) are based on US biodiesel conversion plants that are also used by (Mulugetta 2009). All input data can be found in Table 4B-13 in the Appendix. The calculated NPVs for jatropha production in setting 25-41 is shown in Figure 4-7.

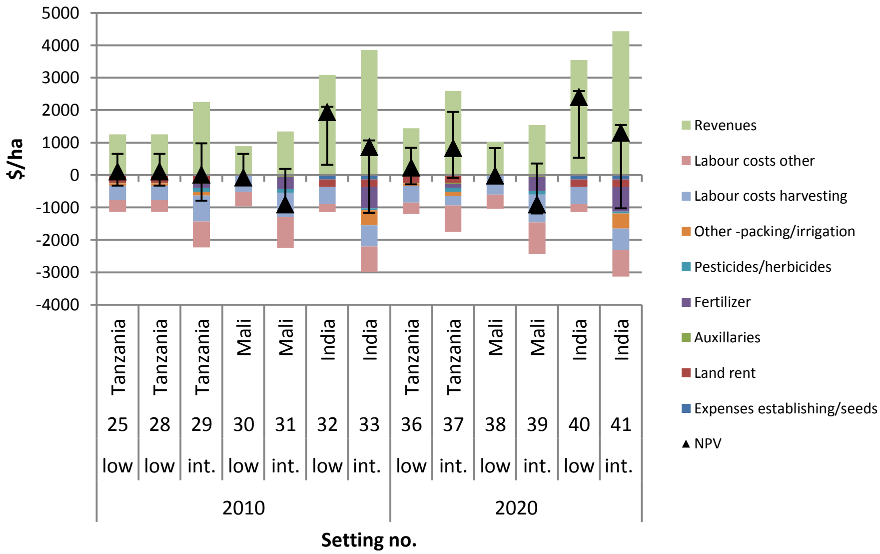


Figure 4-7: Costs, revenues and NPV for jatropha settings 25-41 (excluding plantation settings 26,27,34 and 35) over a lifetime of 24 years, all smallholders, low=low inputs, int.=intermediate inputs, the difference between setting 25 (SVO) and 28 (FAME) is the fuel output, the NPV error bars show the response of the NPV to a market price variation of jatropha seeds of 0.09-0.20 $/kg.

For quite a number of settings the NPV is negative. The profitability for farmers mainly depends on the yield that can be obtained and prices that are paid for the seeds (Van Eijck et al. 2012). Only with relatively low labour costs (or family labour when there are limited other options) and an average yield (2.3 ton/ha/yr) the NPV can reach values above 2,000 $/ha (India, setting 40). The upper range of the market price, 0.20 $/kg would make jatropha production profitable in all settings, but the lower range, 0.09 $/kg would lead to unprofitable production (taking a wage rate of 2 $/day into account). In our calculations, there is no value for the by-product jatropha seedcake assumed for smallholder producers. However, if a jatropha processor can sell this seedcake (as briquettes or charcoal), the price paid for seeds could increase to 0.20 $/kg, it already reached almost 0.19 $/kg in Tanzania at this moment (personal communication, EcoCarbone 2013).

The two plantation settings are different in their production system and cost structure, in setting 26 (mechanized labour) production costs per kg are 0.24 $/kg seeds, while in setting 27 (manual labour) these costs are 0.26 $/kg seeds. The difference is due to the relatively high price of the harvester, which is expected to decrease in the future (for more details see (Van Eijck et al. 2013).

The cultivation of Jatropha is very labour intensive. That is why wage rates have a large influence on feedstock production costs. The wage rate of India is relatively low (1.29 $/day[12]), compared to Tanzania (2 $/day (Van Eijck et al. 2012)). The wage rate of Mali is (slightly) higher with 2.47 $/day (API Mali 2010). Intermediate inputs in India also includes irrigation which is why these settings (33 and 41) have higher costs than cultivation without irrigation (32 and 40). Figure 4-8 shows the total production costs of Jatropha SVO and biodiesel in Tanzania, Mali and India.

[12] This is the minimum agricultural wage (Rs 60/day) (Altenburg et al. 2009)

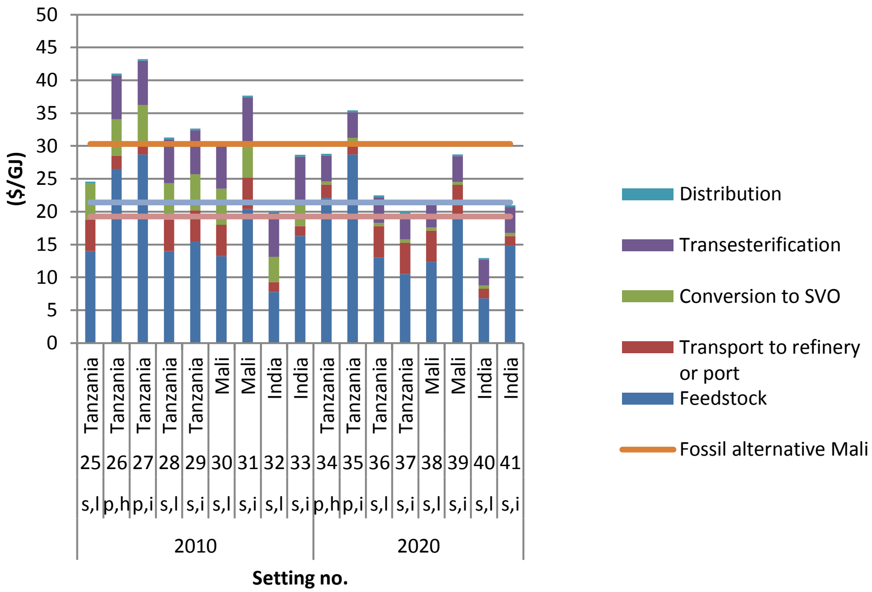


Figure 4-8: Costs per GJ for Jatropha SVO and Biodiesel for setting 25-41, compared to the price per GJ of the locally available fossil diesel (fossil alternative Tanzania is based on diesel price minus government taxes and dealers profit, see (Van Eijck et al. 2012), fossil alternative Mali and India represent the retail price of diesel in Mali and India respectively, based on (GTZ 2009a)) s=smallholders, p=plantation, l=low inputs, i=intermediate inputs, h=high inputs.

Jatropha can be produced for 20-42 $/GJ in 2010 and 13-25 $/GJ in 2020. Transport expenses are quite low in India compared to the African countries. If infrastructure improves these costs can be lowered but this has not been taken into account in the analysis.

In almost all settings, jatropha biodiesel is currently not competitive with fossil fuel. If wages are very low (eg. In India) or if yields are increased (settings 34-41) in 2020, jatropha based biofuel production becomes more promising but there is still a large variability (and thus uncertainty) of 13-35 $/GJ.

The wage rate has a large influence on the costs, due to the high labour requirements for harvesting. Yields are currently quite low, since this is a relatively new commercial crop, but there is room for improvement. The NPV is high when low amounts of inputs are used, whereas high amounts of expensive fertilizer decreases profitability up to a point where farmers can make a loss. With low wage rates (e.g. family labour) profitability is reasonable, but conversion and transesterification costs have to be reduced to rates similar to US conversion plants (0.02 $/l), used in the 2020 settings, which is likely if more commercial experience is gained with processing jatropha oil, to make the endproduct competititve with fossil diesel.

Cassava

Cassava is currently cultivated in large parts of the world, often by subsistence farmers as source for food. Cassava roots can be stored in the soil for two years, serving as food storage (Elbersen and Oyen 2009b). Small scale farmers cultivate cassava as an additional crop on their land, and in between other crops. These cultivation management techniques are often far from best practice. In Thailand, more commercial farming of cassava exists and the first (pilot) cassava to ethanol conversion plants have already been established. In Mozambique the first ethanol plant has been established as well (in Sofala province, capacity of 2 M liters/year) but in Tanzania such facilities do not exist yet. Data on cassava cultivation is obtained from (Van Eijck et al. 2012), IIAM Mozambique, (Nguyen et al. 2008), (Silalertruksa and Gheewala 2009) and through personal communication with Prof. Gheewala (The Joint Graduate School of Energy and Environment, King Mongkut’s University of Technology Thonburi, Bangkok, Thailand), Thea Shayo in Tanzania (Shayo feb. 2010), Sicco Colijn and Boris Atanassov in Mozambique (2010, 2012).

The NPV for producing cassava feedstock in the different settings (42-56) is shown in Figure 4-9. The current market price for fresh cassava roots is based on the food market price, since there are hardly ethanol producing facilities yet. Revenues are based on farm gate prices for fresh cassava roots, which is 58 $/ton in Mozambique, 91 $/ton in Tanzania and 45 $/ton in Thailand (the average during 2006-2008). Prices for fresh roots fluctuate due to seasonal influences and supply and demand. In Thailand the price ranges between 35-70 $/ton$_{fresh}$during the same time frame. In Mozambique prices range between 23-94 $/ton$_{fresh}$[13] and in Tanzania 55-109 $/ton$_{fresh}$ which is included in the NPV sensitivity analysis (Sewando 2012; Van Eijck et al. 2012) Differences between the countries are especially due to high transport expenses for buyers in Tanzania and Mozambique. Sometimes the farmers have to account for the transport expenses themselves. The amount of labour days for Thailand is much lower (around 44 days/ha/yr (Nguyen et al. 2008)) but the use of agricultural equipment is higher. The labour costs for Thailand are

[13] Prices for dried cassava are around 150 $/ton delivered to the factory gate of a cassava ethanol plant in Mozambique (Personal communication, manager Cleanstar)

based on averages from 2005-2008 (Office of Agricultural Economics (OAE) 2009). There are no costs for fertiliser included in the low input settings for Mozambique and Tanzania. This is done because the fertiliser applied is expected to be derived from manure that is freely available. The input costs for Thailand are averages from 2005-2008 (Office of Agricultural Economics (OAE) 2009). The amount of labour required for cultivation in Mali and Tanzania are expected to reduce in 2020 to only half of the amount of 2010. This is due to increased mechanisation that enables labour rates more equal to Thailand. The labour requirements for Mozambique and Tanzania are based on (Van Eijck et al. 2012). 142 labour days per year are required for the low input system and 165 days/ha/yr for the intermediate input systems. The difference is due to the labour days required for additional management such as fertiliser, pesticide and herbicide application and pruning. Since there are currently no large scale plantations for cassava cultivation, these are only included for 2020, when it is expected that commercial plantations could start up.

Cassava is harvested every year, but a fair comparison with other systems in this study, a lifetime of 24 years is used. In the low input system in Mozambique and Tanzania it is assumed that due to poor fertiliser application, the yields decline by 2% per year. In Thailand, current practice is to apply fertiliser, therefore yields are assumed to be stable over the years. For the settings that relate to 2020, it is assumed that Mozambique reaches yield levels of Tanzania, and Tanzania reaches yield levels of Thailand without declining yields over the years, see Table 4B-14 and Table 4B-15 in the Appendix for more details.

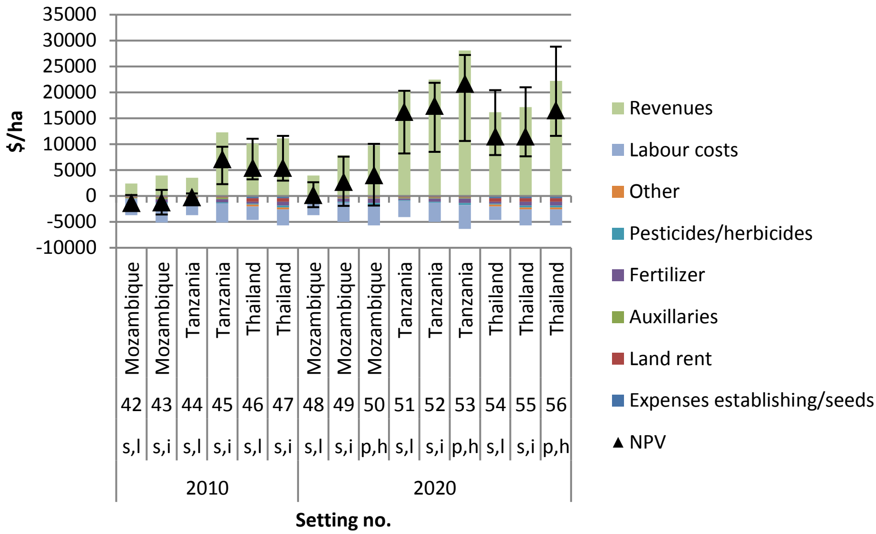


Figure 4-9: Costs, revenues and NPV for cassava in settings 42-56, ($/ha), s=smallholder, p=plantation, l=low inputs, i=intermediate inputs, h=high inputs, lifetime is 24 years, the NPV upper and lower limit is calculated using market value ranges for fresh roots in Mozambique 23-94 S/ton, Tanzania 55-109 $/ton and Thailand 35-70 $/ton.

Except for the 2010 settings (42, 43 and 44) with low yields, all NPVs are positive ranging from 180-16,500 $/ha/lifetime. In 2010, settings 45, 46 and 47, are still profitable (Tanzania and Thailand) with NPVs of 2,200-5,000 $/ha. This is due to the higher yields that make up for additional expenses on fertiliser and other inputs. Fresh cassava roots need to be marketed relatively fast, unless they are dried. All settings that relate to 2020 (setting 48-56) have positive NPVs (from 180-16,000 $/ha) and excluding the low input setting in Mozambique (setting 48), the range is higher with 2,800-16,000 $/ha). The NPV is quite sensitive towards changes in market prices, especially in Mozambique, all settings have negative NPV values when the lower market price is used. In the other countries even low prices result in a positive NPV. Labour costs are the major cost contributor, while for Thailand land rent is also a relatively large contributor. The yield and cassava price have a large effect on the profitability.

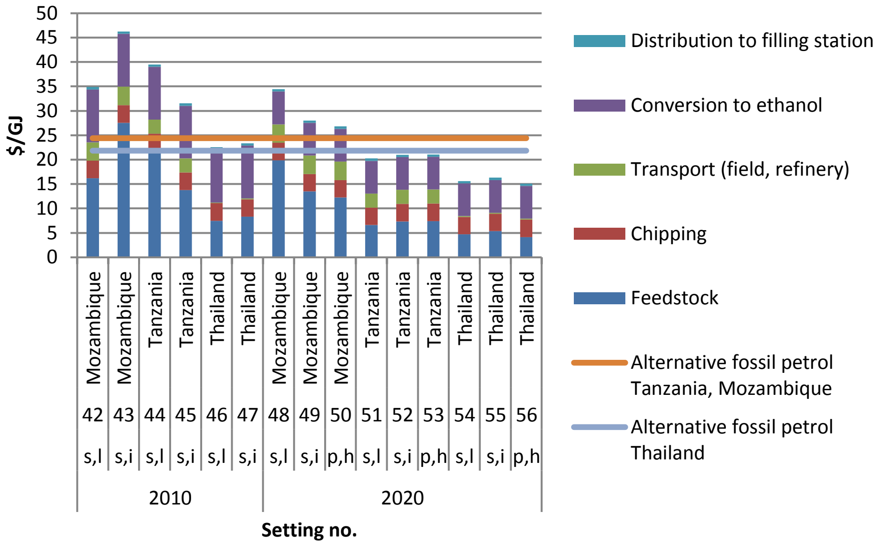


Figure 4-10: Total production cost calculations for cassava ethanol (20.88 MJ/L), s=smallholder, p=plantation, l=low inputs, i=intermediate inputs, h=high inputs. Alternative fossil petrol price Tanzania and Mozambique based on (Van Eijck et al. 2012), in Thailand based on data provided by prof. Gheewala. See table 4A-8 in Appendix A for setting specifications.

Figure 4-10 shows the costs of cassava ethanol production for the different settings in Tanzania, Mozambique and Thailand. Cassava ethanol can be produced in our study between 22-46 $/GJ in 2010 and between 15-21 $/GJ in 2020. In 2010 prices, none of the settings can obtain cassava ethanol for costs below current fossil petrol prices. However, with anticipated increase in yields (in Mozambique from 4-6 to 6-15 tons/ha, in Tanzania from 6-12 to 20-27.5 tons/ha and in Thailand from 20-22 to 32-44, while even yields above 55 ton/ha are possible according to (Silalertruksa and Gheewala 2010) and a reduction of conversion costs from 0.23 $/l to costs equal to corn ethanol conversion costs (0.14 $/l (Hettinga et al. 2009) which implies large scale factories and is based on US conditions), all 2020 settings could be competitive to current fossil petrol prices, except in Mozambique where yields are very low. The price of 0.23 $/l is derived from a pilot factory in Thailand where efficiency improvements and cost reductions are likely. Total costs for cassava ethanol in Tanzania and Thailand are between 15-21 $/GJ, which is lower than the estimate of IPCC (26 $/GJ in Thailand) (Chum et al. 2011).

4.3.2 Production costs of second generation biofuels

Second generation biofuel feedstocks largely consist of cellulose, hemicellulose and lignin (Zinoviev et al. 2010; Chum et al. 2011). Conversion to bioethanol fuel (EtOH) is via hydrolysis of the cellulose and hemicellulose to sugar, after which fermentation of sugar is performed. These feedstocks can also be converted to fuel via gasification or pyrolysis to produce synthetic diesel, bio-oil and other fuels (Batidzirai et al. 2012b; Bacovsky et al. 2013).

Generally, the advantage of next generation biofuels (over 1st generation biofuels) is their ability to utilise many different types of lignocellulosic materials as feedstock and lower land use impacts (FAO 2008b; OECD/IEA 2010; Chum et al. 2011). However, the environmental impact of lignocellulosic biofuels depends on the conversion route, the feedstock and site-specific conditions. Moreover, unlike the mature 1st generation biofuels, 2nd generation biofuel technologies are still under development (pilot and demonstration stages), and commercialisation is anticipated in the next decade (Batidzirai et al. 2013).

We present below the estimated costs for producing 2nd generation biofuels from eucalyptus, switchgrass, poplar, wheat straw and rice straw. Similar to first generation biofuels, at each stage in the production of biomass, cost factors such as labour, machinery investment, fuel costs as well as chemical and energy inputs have to be accounted for. The technical specification of equipment such as tractors is also incorporated into the calculations. An important aspect in energy plantations, especially short rotation woody crops such as eucalyptus, is the ability to coppice over successive rotations periods until it is finally stumped out and replanted.

It is assumed that all feedstock production systems are carried out under well managed agricultural systems - meaning the proper application of appropriate amounts of fertiliser (to replenish plant nutrient extraction and support high biomass growth), pesticide and herbicides (to ensure protection of energy crops against diseases, pests and weeds). It also assumes adequate silvicultural management, but does not take into account irrigation. Planting is assumed to be done during the rainy season to take advantage of rain-fed growth. However, some water may be applied to young seedlings, during the first three weeks of growth, should they encounter moisture stress. More details on the feedstock production and information on conversion technology economics can be found in Appendix C and Batidzirai (2012b) and (2013).

Second generation ethanol production costs from eucalyptus

Eucalyptus is considered as the energy crop for Mozambique and Brazil. In Mozambique, it is assumed that seedlings are planted manually at a spacing of 3x3-m in a semi-arid region. Extensive manual weeding and chemical pesticide application are required during the first 3 years, before the eucalyptus trees reach full canopy cover. Harvesting is carried out every 8 years over 24 years before the stand is re-established. It is assumed that in Mozambique, harvesting is done using chainsaws. Forwarding to the roadside is done using a skidder. Table 4C-16 in appendix C gives details of cost elements included in eucalyptus production in Mozambique.

Eucalyptus productivity in Mozambique is estimated to vary from 4.5 to 35 t_{dm}/ha (Ugalde and Pérez 2001; Laclau et al. 2003; Batidzirai et al. 2006; Savcor 2006; Van Eijck et al. 2012). For a given species, the biomass yield is a function of the management applied as well as climate and soil conditions. According to Van der Hilst and Faaij (2012), the mean annual increase (MAI) is estimated to be 1.5% per annum. The projected maximum attainable yield in 2030 is still well below the estimated maximum attainable yield for Mozambique.

Similarly, for Brazil, eucalyptus production costs are estimated using a set of assumptions shown in Table 4C-18 in Appendix C. Land rent differ depending on soil quality and range from 49-146 \$/ha. Harvesting is assumed to be mechanised using Claas harvesters. Current Brazilian average yields of eucalyptus are around 42 $m^3ha^{-1}yr^{-1}$ (~15 $odt.ha^{-1}yr^{-1}$), from very marginal soils to the very suitable soils (Machado et al. 2013)[14]. Projections for the Brazilian potential average vary, but are generally estimated to be around 50 m^3 ha^{-1} yr^{-1} (~18 $odt.ha^{-1}yr^{-1}$) (IPEF 2008; ABRAF 2009; SBS 2009).

Eucalytpus feedstock production costs are calculated to be 3.9 \$/GJ in 2020 and 3.3 \$/GJ in 2030 in Mozambique and at the farm gate. For Brazil, production costs are 2.4-3.3 \$/GJ in 2020 and 2.2-2.9 \$/GJ in 2030 depending on land quality, see Table 4-4. These costs are dominated by fertiliser and harvesting costs.

Table 4-4: Eucalyptus production performance in Brazil and Mozambique on different land quality

	Region	2020		2030	
Land quality →		Suitable	Less suitable	Suitable	Less suitable

[14] The productivity of eucalyptus in Brazil is estimated to be 35-55 $m^3ha^{-1}yr^{-1}$ (Machado et al 2013). Smeets and Faaij (2009) give a range of 10 to 29 odt $ha^{-1}yr^{-1}$, the higher end representing very suitable soil quality.

Yield (t_{dm} ha^{-1} yr^{-1})	Brazil[a]	22	10	24	12
	Mozambique[b]	-	7	-	10
Production costs (USD/t_{dm})	Brazil[a]	2.4	3.3	2.2	2.9
	Mozambique[b]	-	3.9	-	3.3

Source: [a] (Smeets et al. 2009); [b] (van der Hilst and Faaij 2012)

The EtOH conversion technology route considered here involves use of physical and acid pretreatment followed by enzymatic saccharification of the remaining cellulose after which the resulting sugars undergo enzymatic fermentation to produce ethanol. A base capacity of 400 MW_{th} input capacity is assumed at a load factor of 90% (see Table 4-5). Investment costs are expected to decline from 374 M$ in 2020 to 290 M$ in 2030 due to learning effects in conversion technology.

For BtL conversion, the technology route considered is a combination of circulating fluidised bed gasification and turbular fixed bed FT reactor. A base scale of 400 MWth in is also assumed at a 90% load factor. Investment costs are expected to decline from 422 M$ in 2020 to 327 M$ in 2030 due to learning effects in conversion technology.

Table 4-5: Summary of biofuel conversion technology costs

Conversion factor	Next EtOH [a]		Fischer Tropsch CFB [b]	
	2020	**2030**	**2020**	**2030**
Base Scale ($MW_{th\ LHV\ out}$)	160-400	160-400	180-400	180-400
Base Investment (\$/$MW_{th\ LHV\ out}$)	935-2020	840-1820	1140-3310	1130-2990
Scale factor	0.7	0.7	0.78	0.78
Lifetime	25	25	25	25
Load factor	90%	90%	90%	90%
O&M (% of investment)	4%	4%	4%	4%
Efficiency fuel only (LHVwet)	40%	40%	45%	45%

Source: (Hamelinck et al. 2005; Vogel et al. 2007; de Wit et al. 2010; Chum et al. 2011)

[a] According to Carriquiry et al. (2010), capital investment costs for a 220 million litres per year cellulosic ethanol plant using 700,000 tonnes wood or switchgrass as feedstock are between 264 and 352 M$. They estimate the capital investments to be in the range of 1.06 -1.48 $/litre ethanol annual capacity while operational costs are between 0.35-0.45 $/litre depending on feedstocks and technology. Future capital investments are expected to reduce to 0.95-1.27 $/litre ethanol annual capacity and operating costs to 0.11-0.25 $/litre ethanol. NRC (2009) gives capital costs for a 40-million-gallon bioethanol facility as 174-223 M$ using poplar woodchips as feedstock. Corresponding costs with miscantus, switchgrass, corn stover and wheat straw as feedstock are given as 176, 156, 150 and 123 M$. For different production capacities of 20, 40, 60, 80 and 100 million gallons per annum, the investment cost are respectively 117, 194, 264, 329 and 349 M$. Zinoviev et al (2010) estimate the investment costs for

next generation bioethanol plant capacities of 15-185 $MW_{biofuel}$ to be 30 to 325 M€ to give specific TCI of 1800-2000 €/$kW_{biofuel}$. Chum et al (2011) compare costs of advanced bioethanol production technologies from various studies and give capital costs of 0.9-1.3 $/litre ethanol annual capacity for plants in the range 150-380 million litres/yr. They estimate a 25% and 40%reduction in operating costs by 2025 and 2035 respectively.

[b] Batidzirai et al (2013) give the investment cost of BtL based on integrated gasification-Fischer Tropsch (IG-FT) technology using direct pressurised oxygen blown gasification (169 MW: 15MWe + 154 MW_{fuel})at 332 M$. Zinoviev et al (2010) estimate the investment costs for FT fuel plant capacities of 130-220 $MW_{biofuel}$ to be 430 to 1000 M€ to give specific TCI of 2300-3480 €/$kW_{biofuel}$. According to Vogel et al (2007), BtL investment costs for the CFB technology are 543 M$ for a 500MWth in scale (excluding 122.5 M$ pretreatment costs). NAS (2009) estimates the cost of FT production based on a facility of 1.1 million t_{dm} switchgrass feedstock (3940 tons/day) to be 636 M$. The facility is designed for producing 4410 bbl/d and 35MWe. Chum et al. (2011) also give FT production costs of 17 $/GJ biofuel for 80 million litre annual production capacity, 8 $/GJ biofuel for a 280 million litre facility.

Figure 4-11 provides a comparison of next EtOH production costs from eucalyptus in Brazil and Mozambique. At current conditions, EtOH could be produced at 19.8 $/GJ (in the range 14.5-30.3 $/GJ) in Mozambique and between 16.8 $/GJ (14-30 $/GJ) and 19.4 $/GJ (14.1-30 $/GJ) in Brazil. Corresponding long term costs are 18.5 (12.3-24.6) $/GJ, 16.9 (12.3-24.6) $/GJ and 16.2 (11.7-24.3) $/GJ. The range of values given in brackets represents the uncertainty in investment costs as found in literature.

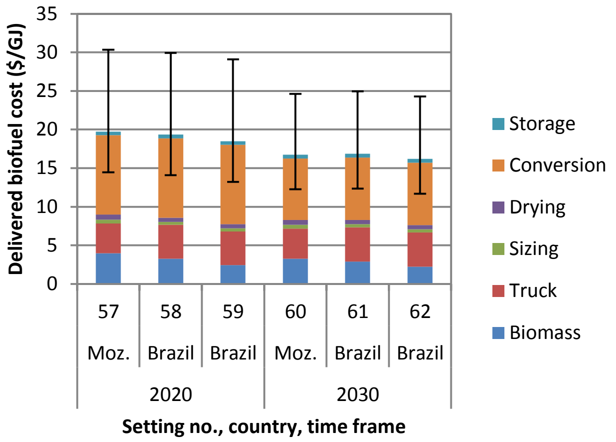


Figure 4-11: Eucalyptus to next EtOH production costs (Moz=Mozambique and Brazil), the two settings in Brazil represent less suitable land (58, 61) and suitable land (59, 62).

Conversion costs dominate overall costs, accounting for around half of the production costs. The higher biomass feedstock production costs on marginal land explain the high fuel costs in setting 57 and setting 58 (Brazil less suitable land). EtOH is produced at marginally higher costs in Mozambique mainly due to lower biomass productivity and higher feedstock production costs. Truck transportation is also a significant factor in overall costs contributing up to 27% of total fuel production costs.

Poplar (BtL production costs in Ukraine)

Currently there is no poplar production in Ukraine except for a few test plantations. Studies indicate that the optimal planting density of seedlings in Ukraine would be 4,000-6,000 plants/ha (Fuchylo Y. D. et al. 2009). We assume a planting density of 5,300 with 2 year rotation over 10 years. Poplar productivity is estimated to be 6 and 14 tdm $ha^{-1}yr^{-1}$ in marginal areas and suitable soils respectively. Table 4C-17 (Appendix C) shows the amounts of fertiliser input requirements by land suitability. Wages vary from 0.63-2.1 $/hr, while land rent is about 38 $/ha. Fuel costs range from 960 $/ton for diesel to 1080 $/ton for petrol. The current interest rate in Ukraine is 17% (SEC Biomass 2011).

Poplar production costs are calculated to be 3.5 $/GJ on marginal soils in the short term, decreasing to about 3 $/GJ in 2030. Similarly, on good quality land, poplar can be produced at a cost of 2.3 $/GJ in 2020 and at 2 $/GJ in 2030. As shown in Figure 4-12, harvesting represents the largest cost component for both marginal (35-38%) and good soils (29-31%), with the latter representing the long term. Fertilisation is also an important cost component contributing up to 29% of poplar production cost.

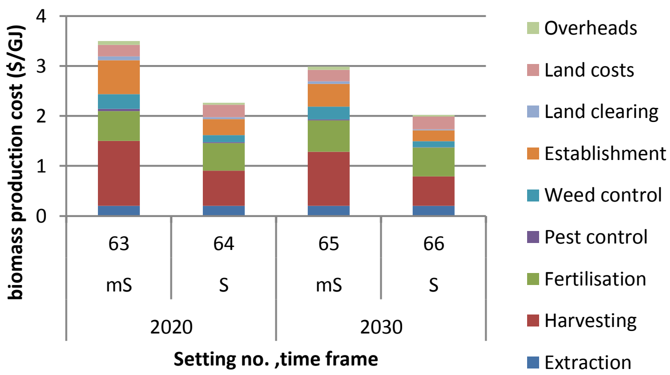


Figure 4-12: Poplar production costs in Ukraine by component (mS=marginally suitable land, S=suitable land)

We assume poplar is used as feedstock to produce biodiesel in a BtL plant. The BtL conversion technology route considered is a combination of circulating fluidised bed gasification and turbular fixed bed FT reactor. A base scale of 400 MWth in is also assumed at a 90% load factor. Investment costs are expected to decline from 422 M$ in 2020 to 327 M$ in 2030 due to learning effects and increased efficiency in conversion technology (See Table 4-5).

BtL production costs in Ukraine are estimated to be 13.9-17.8 $/GJ for the selected settings under the base case, with the latter representing production on more marginal land in the short term. If variations in investment costs are taken into account the BtL production costs are calculated to be 11-42 $/GJ as shown by the error bars in Figure 4-13. There is a 16% difference in costs between the short term and long term, mainly attributed to learning effects in agricultural production and conversion technology. See Figure 4-13. Feedstock production costs and conversion costs dominate total costs, at 14-20% and 57-65% respectively. Truck transport has a lower impact on overall costs (12-16%) due to the shorter distances assumed for Ukraine compared to other countries.

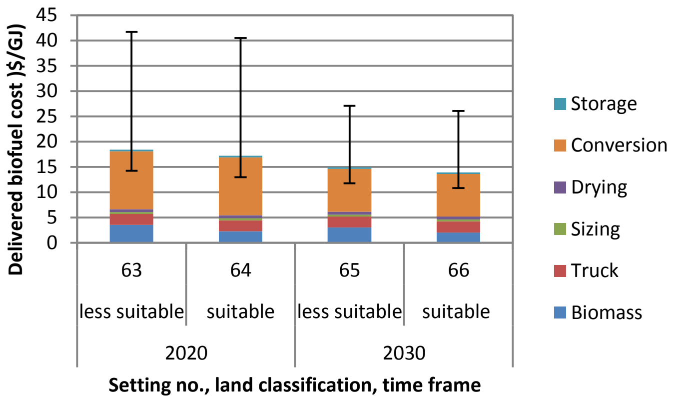


Figure 4-13: Poplar to synfuel production costs (all Ukraine)

Switchgrass (next ethanol and synfuel production costs in Argentina)

Switchgrass is already being produced in Argentina and is mainly used for livestock forage production (INDEC 2002). It is assumed that the switchgrass plantation is established on marginal soils using imported seeds and the plantation is expected to last a lifetime of 15 yrs before it is re-established. The productivity for switchgrass on marginal land is assumed to be 5 tdm/ha/year. Future yield increases are estimated to be between 32-67% in 2030 compared to the current situation (van Dam et al. 2009a).

Land rent in Argentina ranges from 100 to 300 US$/ha/year depending on land suitability type and location. In 2030, land prices for marginal land remain constant; however for good quality land prices go up from 300 to 450 $/ha. Labour wages range from 2.18-3.18 $/hr and in 2030; labour rates are expected to go up to between 3.98-8.29 $/hr. Switchgrass seeds are imported from Texas at 20 US$/kg compared to a possible local production cost of only 10 US$/kg. Fertiliser costs in Argentina vary from 0.315 US$/kg (P) to 0.48 US$/kg (N) (Margenes 2006). Aggregate switchgrass input production costs per hectare are shown in Table 4C-20 in Appendix C.

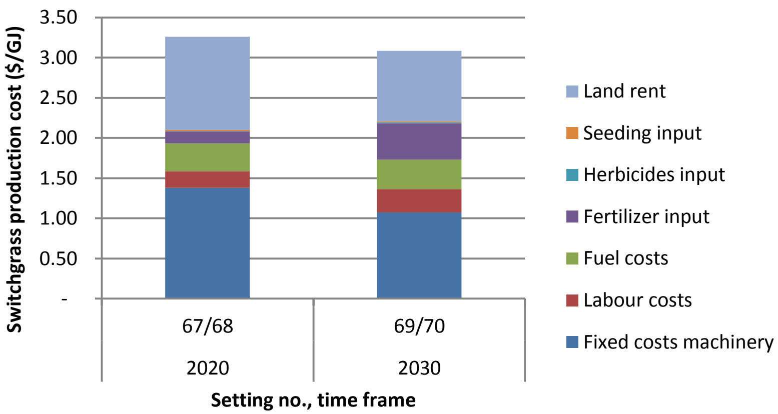


Figure 4-14: Switchgrass production costs in Argentina by component (for EtOH (setting 67, 69) and BTL (setting 68,70)

Switchgrass production costs are calculated to be 3.2 $/GJ (306 $/ha) in 2020 and 3.0 $/GJ by 2030. See Figure 4-14. The major cost elements in switchgrass production are machinery costs (37% short term and 44% for long term). Land costs are also significant (at 29% in 2020 and 36% in 2030). Fertiliser costs increase significantly from 3% in the short term to 12% in the long term.

A comparison of BtL and EtOH production from switchgrass in Argentina shows that EtOH production costs are marginally higher (18.5 - 21.0 $/GJ) compared to (18.3 - 20.8 $/GJ) for BtL. This is mainly attributed to the higher conversion efficiency for

BtL, which offset the higher BtL investment costs. As shown in Figure 4-15, conversion costs are dominant in the overall costs (43-52%) while truck transport costs are also significant at 23-29%. Storage of switchgrass bales and produced fuel also contributes up to 10% of overall costs. Similarly, biomass production costs are also significant at 16%.

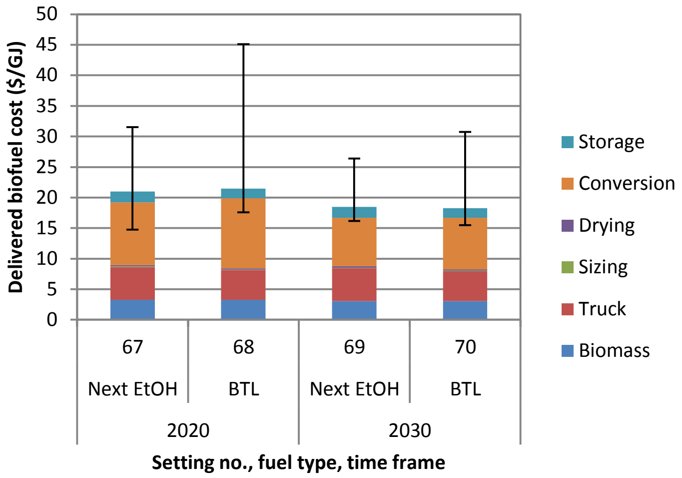


Figure 4-15: Switchgrass to ethanol and synfuel production costs (all in Argentina)

Rice and wheat straw (next ethanol production in China and Ukraine)

Rice and wheat straw have advantages as biomass feedstock because utilising them does not require recovering land costs, which are already covered in the grain enterprise (Batidzirai et al. forthcoming). The cost of the straw supply is taken as the opportunity cost of the agricultural residue at a grain plantation (usually taken as its fertiliser value or alternatively compared to the next application such as fodder) (Gallagher et al. 2003). Cost elements include chopping/cutting/swathing, raking, baling and on-farm hauling of crop residues. Because unused residues may have value (in that they reduce fertiliser needs or soil erosion), appropriate adjustments must be included in cost estimates. However, estimating nutrient requirements is very site specific and needs detailed soil analysis to evaluate sustainable residue removal rates (Batidzirai et al. forthcoming). Due to lack of data in this case, we used a sustainable residue removal rate of 1 t_{dm}/ha/year estimated by SEC Biomass (2011) and we assume that nutrient compensation costs are negligible.

Wheat straw production in Ukraine

Table 4C-21 (in Appendix C) shows the cost estimates for wheat straw collection and packaging in a typical Ukrainian facility. Sustainable wheat straw yields are estimated to be about 1 tons per ha at 15% moisture content (SEC Biomass 2011).

The production cost of wheat straw is estimated to be 2.9 $/GJ in 2020 and 1.9 $/GJ in 2030. As shown in Figure 4-16, cutting and raking wheat straw contributes nearly 50% of the total straw costs. Baling is also a significant cost adding another 25% to the overall costs while bale collection and forwarding (roadsiding) also contributes about 21%.

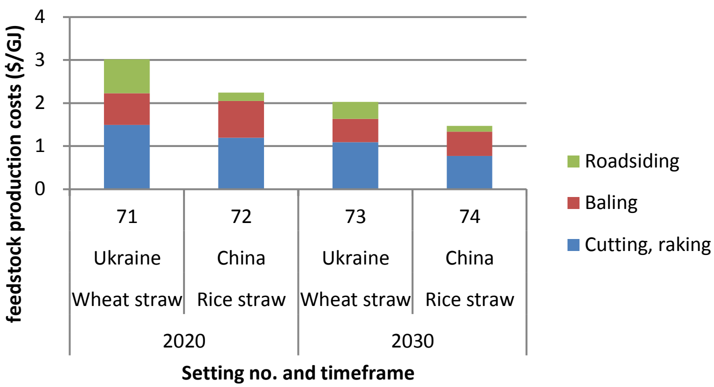


Figure 4-16: Wheat and rice straw production costs in Ukraine and China by component

Rice straw in China

Production of rice straw also involves swathing, raking, baling and roadsiding as shown in Figure 4-16. Sustainable rice straw yield is assumed to be about 1 ton/ha. Rice straw is estimated to cost 2.2 $/GJ in 2020 and 1.5 $/GJ in 2030 at the farm gate in China. Swathing and baling dominate the overall costs at 43% and 38% respectively, both in the short term and long term. Raking and roadsiding contribute about 10% each.

Next generation ethanol production from straw is estimated to cost between 20 and 26 $/GJ in China and Ukraine. EtOH production from wheat straw in Ukraine is cheaper at 20-23 $/GJ compared to production from rice straw in China (23 - 26

$/GJ). The differences between the two countries can be attributed to the longer truck transport distances considered for China, which contribute 31-35% of the total costs compare to 20-23% for Ukraine. Contribution of conversion costs is comparable for the two countries at about 35-44%. As shown in Figure 4-17, storage costs for straw bales and produced ethanol are also high, contributing between 20 to 26% of overall costs. Feedstock (straw) costs are relatively low compared to other cost elements (and other supply chains) at about 6-26%.

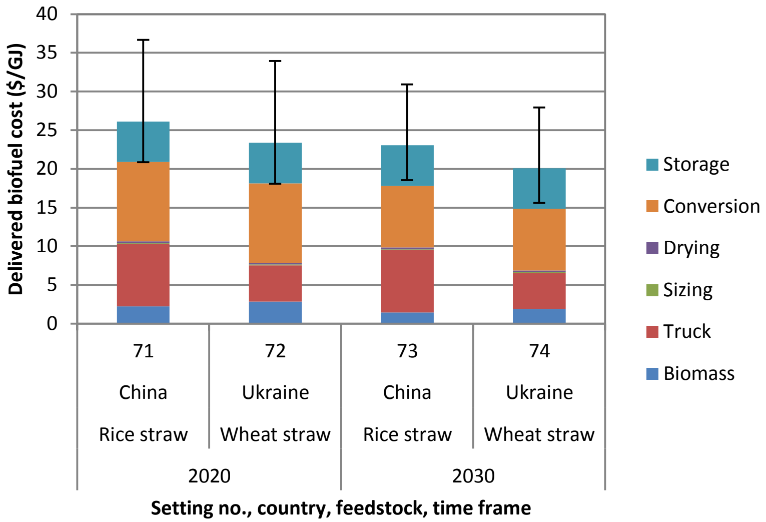


Figure 4-17:Straw to EtOH production costs (China and Ukraine)

4.3.3 Overall cost overview 1st and 2nd generation biofuels

Comparison of biofuel production costs by feedstock type

Figure 4-18 shows the total production cost ranges found for all first and second generation biofuels in all settings considered (including the uncertainty ranges for 2nd generation feedstocks).

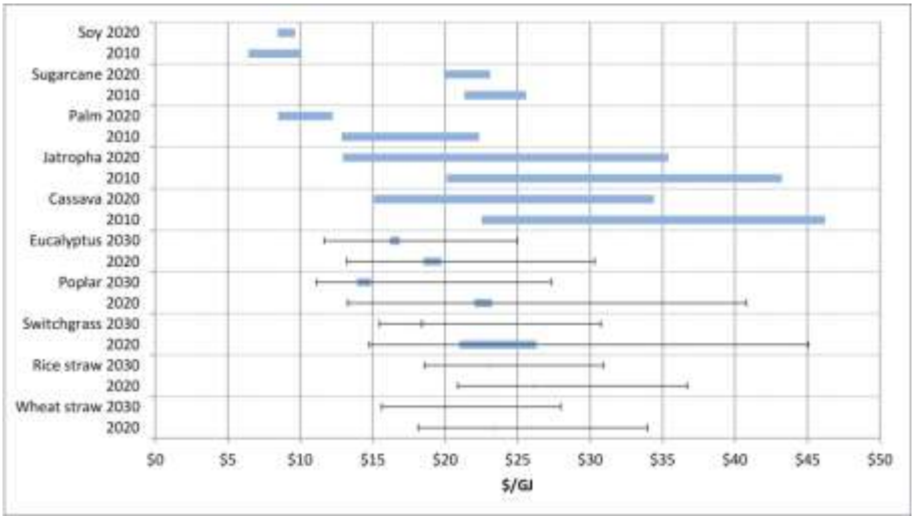


Figure 4-18: Overview of biofuel production costs by feedstock type including all settings, 2010 and 2020, feedstock type and time frame on vertical axe

The biofuel production costs in 2020 (1st gen.) and 2030 (2nd gen.) are lower than in 2010(1st gen.) and 2020 (2nd gen.) in all cases. Out of all considered feedstocks, soy and palm biodiesel can be produced at lowest costs per GJ, between 8-10 $/GJ and 8-26 $/GJ respectively (soy SVO for 6 $/GJ). Biofuel production from cassava (bioethanol) and jatropha (biodiesel) is comparatively more costly than other biofuel feedstocks and pathways and in many settings more expensive than fossil fuel (≈20-30 $/GJ). However, in 2020 increased yield and low labour costs could lead to competitive cassava and jatropha based biofuels production costs (around 15 $/GJ). Biofuel production from 2nd generation feedstock in the settings considered leads to costs between 13-45 $/GJ in 2020 and 11-31 $/GJ in 2030, of which eucalyptus based bioethanol has the lowest costs (11-29 $/GJ) and switchgrass based biodiesel the highest (17.6-45 $/GJ) - for both the short and long term. For the base case, 2nd generation ethanol is more costly to produce (16-26 $/GJ) compared to 2nd generation biodiesel (14-21 $/GJ), but this depends strongly on assumed conversion costs, which are uncertain as shown by the ranges in costs. First and second generation biofuels do therefore not vary that much from each other. With the right setting all fuels could be produced for costs lower than current fossil fuel costs.

Comparison of biofuel production costs by region

Figure 4-19 shows the biofuel production costs by country included in the analysis. The regions with the lowest production costs for first generation biofuels in 2010 are Argentina (soy biodiesel), Malaysia (Palm biodiesel) and Indonesia (Palm biodiesel). These regions are currently already large producers. In 2020, the same three regions still have low production costs, together with Colombia (Palm oil). The production of soy SVO is only taken into account in 2010, in 2020 it is assumed that Argentina only produces FAME. Thailand and India also offerpromising perspectives, although the range in the case of India is quite large (due to the differences in yields for jatropha) which means there are quite some uncertainties (jatropha oil). In Mozambique, Mali and Tanzania, the production costs (of jatropha biodiesel) are lower in 2020 compared to 2010, there is still a large range.

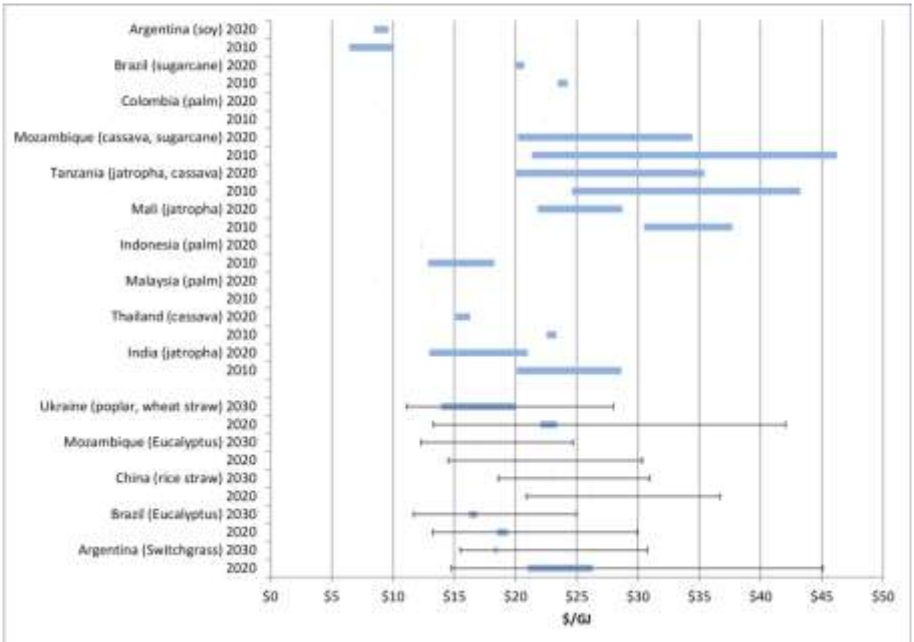


Figure 4-19: Overview of biofuel production costs per region, all settings combined (between brackets the biofuel feedstock base)

For 2nd generation biofuels, production costs are much lower in Ukraine, due to the lower input costs reflected especially through the use of cheaper organic manure instead of chemical fertilisers in the production of poplar. However, the cost of fuel produced from wheat straw is high due to the higher logistical costs such as storage and truck transportation. Biofuel production costs in China are relatively higher than other countries due to the long transportation distances of low energy density rice straw. This is due to low yields per ha and therefore large areas are required. Truck transportation contributes about 8 $/GJ to the overall fuel production costs in China. This demonstrates the need for reducing the energy density of agricultural residues by densification[15] of straw early in the chain to reduce the logistical costs.

4.3.4 Sensitivity analysis

For the 1st generation crops, discount rates and wage rates are varied (market price ranges and the response of the NPV for the raw feedstock are already discussed in earlier sections), and for 2nd generation crops we varied the technological learning and efficiency for conversion facilities, discount rate, and feedstock production costs.

4.3.4.1 1st generation

We varied two parameters, the discount rate and the wage rate, see Table 4-6. In the Result section, the sensitivity of the NPV towards market prices has already been discussed.

Table 4-6: Selected variation in parameters used in sensitivity analysis of 1st generation biofuels production

Parameter	Variation	Original value
Discount rate [%]	6-15	8.2
Wage rate	1-15 $/h (soy) 0-500 $/ha/y (sugarcane) 0-7.5 $/day (jatropha) 0-8 $/day (cassava)	Argentina: 3.18 $/h(2010) and 8.29 $/h(2020) Mozambique: 250 $/ha/y India: 1.29 $/day, Mali; 2.46 $/day and Tanzania: 2 $/day Mozambique: 2 $/day (2010) 4 $/day (2020), Tanzania: 2 $/day (2010) and 4 $/day (2020), Thailand: 3.3-4.3 $/day

[15] We assume straw is transported as bales from the field to the energy conversion facility. It is possible to further densify the straw into pellets or torrefied pellets before long distance transportation, but such options and alternative supply chains were not included in this study.

Discount rates are varied from the original 8.2% to 6% and 15%, see Figure 4-20.

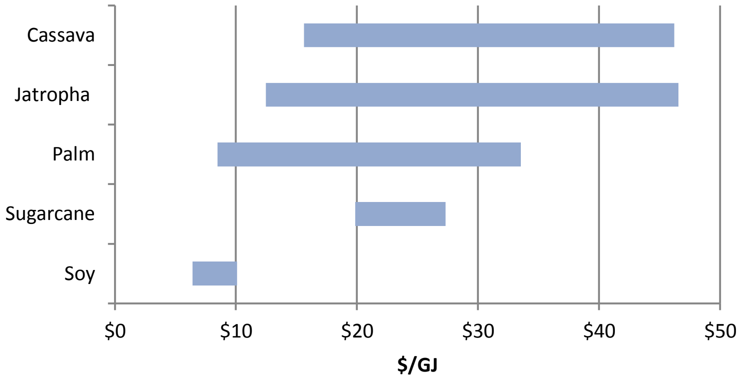


Figure 4-20: New ranges for variation in discount rates, 6%-15%

The range for palm oil is now larger and goes up to 34 $/ha. The range for jatropha is even higher and varies from 12 to 47 $/ha. Still both cassava and jatropha have the largest range, while soy biodiesel (and palm) can be produced against the lowest costs.

Wages/labour costs: Wage rates for Argentina used in the calculations are 3.18 $/h in 2010 and set at 8.29 $/h in 2020. For this sensitivity analysis they are varied from 1 $/h to 15 $/h. Sugarcane labour costs are varied from zero to double (from 250 to 500 $/ha/yr in harvesting years). Palm lacks specific data on labour. Jatropha labour rates are varied from 0 to 7.5 $/day. The zero labour costs represent family labour. And finally for cassava the wage rates are varied from 0 to 8 $/day (8 is the double rate of the 4 $/day that is used for 2020 Moz.).

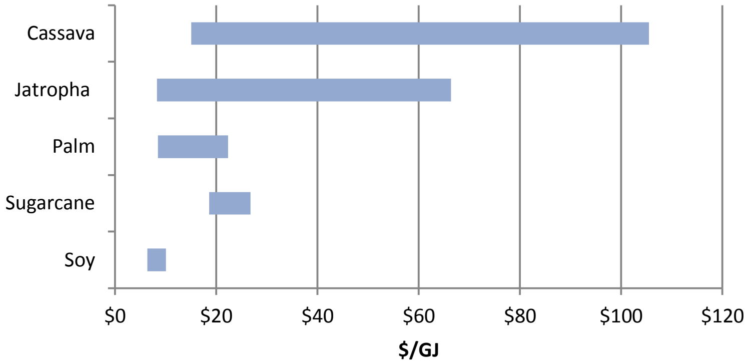


Figure 4-21: New ranges for variation in wage rates, 1-15 $/h in Argentina, 0-500 $/ha/yr in Mozambique, jatropha labour rates 0-7,5 $/day and cassava 0-8 $/day.

The influence of wages is large especially for cassava ethanol, jatropha SVO and biodiesel (influences are only taken into account on labour changes in feedstock production stage). The influence on soy is minimal. The price of inputs has been considered constant.

4.3.4.2 2nd generation

Advanced biofuel production costs depend on a number of factors as already shown by the differences among countries and feedstocks. For feedstock production, the feedstock productivity is important and developments in plant selection and breeding leading to experience/technological learning has a significant impact on future feedstock production costs. At the conversion stage, the capital investment cost and associated cost of capital are the key determinants of the biofuel production cost levels (Meerman et al. 2012; Batidzirai et al. 2013). It is expected that future capital investment costs will decrease with technological learning and scaling up of production facilities (Junginger et al. 2010), but this is uncertain. The variation of these factors is shown in Table 4-7.

Table 4-7: Selected variation in parameter used in sensitivity analysis of 2nd generation biofuels production

Parameter	Variation
Technological learning in conversion facilities (progress ratio)	0.88 - 0.98
Interest rate	6%-15%

Conversion efficiency improvements	- EtOH from 35% to 45%: Base value - 40% - BtL from 40% to 50%: Base value - 45%
Variation in feedstock production costs	Labour increase to 319% in 2030; land rent by 50%; fertiliser by 300%; agrochemicals by 121%

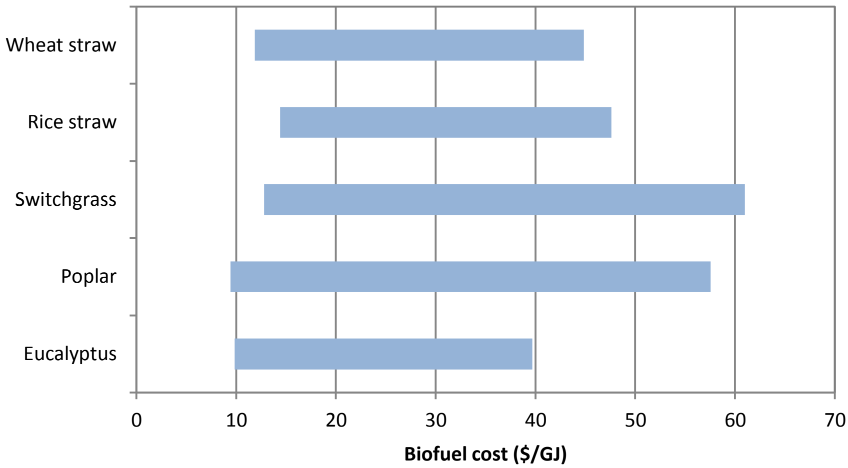


Figure 4-22:Range in 2nd generation biofuel costs by feedstock type for both 2020 and 2030

The sensitivity analysis show large variations in potential fuel production from poplar (9.4-57.6 $/GJ) and switchgrass (12.8-61 $/GJ). The economics of these supply chains are influenced by the future conversion efficiency improvements, which result in lower feedstock requirements and lead to corresponding decrease in logistical costs, especially long distance transport and long term storage of feedstock. All the supply chains are strongly influenced by conversion costs and the lower cost range reflects cheap cost of capital (i.e. 6%) and faster technological learning (progress ration of 0.88). Overall, biofuel production costs vary by 85% from about 10 to 60 $/GJ. The production costs of BtL vary over a much wider range from9.4-61 $/GJ, while 2nd generation ethanol production costs range from 9.8-47.6 $/GJ.

For comparison, recent state of the art analysis estimate that second generation production costs for bioethanol range from 13-30 US$/GJ, while BtL derived fuels are estimated to cost 16-30 US$/GJ (Chum et al. 2011). The differences are mainly due to uncertainties in investment costs, feedstock types and technology configurations.

4.4 Discussion

Across the biofuel value chain, prices of inputs are assumed to remain the same over the decade. But in reality several factors influence these prices. Indirect effects result from the price feedbacks of the economic system: once a commodity is used more, but supply is constrained, prices tend to increase. Depending on the elasticity, the demand for that commodity will adjust to the new price, and this will in turn affect production levels, and hence, adjust prices again. A key issue in these feedbacks is the volatility of prices, i.e. their fluctuations, which can negatively affect both producers and consumers, especially for food and feed. Inflation could increase prices and revenues, while more efficient management techniques, better varieties etc. could reduce prices. Also, fertiliser prices are linked to fossil prices that are highly volatile. The same accounts for the prices included in the NPV calculations for the feedstock production where current market prices are included. These can be highly volatile and will influence the profitability such as the market price for sugarcane that fluctuates with the global sugar prices. The indirect effects are difficult to model as only direct effects of price changes can be monitored, and cause-effect chains must be added to those. This means that indirect effects can be addressed adequately only through complex modeling which allows for (price) feedbacks, substitution, and market segmentation. This study does not carry out own modeling for that. More research is required to quantify these effects.

Second generation biofuel technologies represent an industry for which limited experience with commercial production yet exists (Batidzirai et al. 2012b). A number of technological and economic challenges (especially in final biomass conversion) need to be overcome for the successful commercial deployment of these advanced bioenergy technologies (OECD/IEA 2010; Chum et al. 2011; Bacovsky et al. 2013). A key pre-requisite is that a large, stable supply of lignocellulosic biomass be guaranteed (OECD/IEA 2010). Also, investment in infrastructural development along the biomass supply chain needs to be realised especially in developing countries (Batidzirai et al. 2013). However, there are also opportunities for utilization of agricultural and forestry by-products, which could lead to developing of new supporting industries and skills.

This analysis only takes economic costs into account. Total availability, social and environmental effects are not taken into account. For this analysis we assumed that the biofuels value chains take into account basic sustainability criteria, which implies that the feedstock production does not take place in conservation areas, does not lead to soil erosion etc. which means environmental effects could be minimized and indirect land use change avoided. However, if a project is going to be implemented a detailed socio-economic and environmental impact assessments are still required (Franke et al. 2012; Van der Hilst et al. 2013). A more comprehensive approach would be to conduct a full impact analysis along the biofuel value chain. Meeting strict criteria may also affect biomass production costs to some extent, see Smeets (Smeets and Faaij 2010), this requires further research.

Data on costs, yields and benefits are in this analysis mostly linked to regions. However, the exact costs, labour requirements and yield could be different for specific locations, or vary per year. In addition, other costs might also occur that are not taken into account such as financial costs (costs of acquiring loans), profit margins etc. Also yields willin reality vary, due to e.g. weather conditions etc. We used relative conservative yield estimates for 2020, considering documentation on higher yields that even can be obtained today (such as 25 FFB/year in Indonesia (Wicke et al. 2008). But yield increases can only be obtained when more knowledge is generated in developing countries and better and more efficient management systems are used.

We did not include a cost benefit assessment (NPV calculations) for 2nd generation feedstocks since the markets for these feedstocks are undeveloped or do not exist. Even for biomass feedstocks with a long history of production such as Eucalyptus, the production regime for current markets (mainly roundwood, poles, pulp and paper) is different from production targeting biomass for energy. Energy crop plantations are typically planted with higher stand densities and harvested over shorter cycles (Batidzirai et al. 2006). For residues, many studies use opportunity cost as an indicator of their potential value. The opportunity cost of using crop residues for energy is the value foregone by not using them in a competing application (or the price paid for residues by competing uses). For example, the residue market is expected to reflect the forage value of residue and prices for the close substitute, hay, when the unused residue is exhausted in a local area (Gallagher et al. 2003). As the market develops, residue supply is expected to increase in value when all harvested residue is used by industry. This brings in complex market feedback dynamics which are difficult to model without employing for instance, Computable General Equilibrium models. Nevertheless, from the perspective of a 2nd generation biomass feedstock producer, the viability of biomass production becomes a question of choice between different feedstock types, whereby the feedstock offering higher returns on investment is preferred, also depending on market demands. We assume an efficient biomass production system which optimises the production inputs so as to deliver biomass at lowest possible production costs. For residues which are not currently being marketed, the only production costs are for collecting and baling the biomass at the farm and typically a profit margin as well as 'farmer compensation' for fertiliser value of biomass are included in the cost build up (Batidzirai et al. forthcoming), ensuring the viability of the producer.

4.5 Conclusions and recommendations

High NPVs are calculated for cassava and palm. But cassava can also have a negative NPV which indicates that the project investment is not robust if yields are (very) low. The calculated NPVs for jatropha also range from negative to positive, while for sugarcane and soy the NPV is more robust (always positive), these crops are also less sensitive towards changes in discount rates and wages. Results from the current study can be used as benchmark, to identify the ranges in cost prices of 1st and 2nd generation feedstocks per region. Total production costs in 2010 are estimated to vary between 6-45 $/GJ for 1st generation feedstocks in the chosen settings and from 8-35 $/GJ in 2020. For 2nd generation biofuels, production costs are estimated to be 17-26 $/GJ in 2020 and 14-23 $/GJ in 2030., BtL production costs range between 14 and 21 $/GJ while advanced EtOH costs 16-26 $/GJ. Poplar based biodiesel production in Ukraine has the lowest costs (14-17 $/GJ) and rice straw based bioethanol the highest (23-26 $/GJ) - for both the short and long term. Key to the competitive production of 2nd generation fuels is the optimisation of the conversion process, which dominates overall production costs (conversion costs range from 35-65% of total supply chain costs). Also important is the efficient organisation of supply chain logistics, especially for the low energy density feedstocks such as wheat straw - the handling, storage and transportation of bulky agricultural residues requires densification of the feedstock early in the chain to reduce subsequent step costs. For wheat and rice straw, storage costs account for up to 20% while their truck transportation accounts for up to 35% of the total supply chain costs. Feedstock production costs are also important for the selected energy crops, feedstock costs account for 20% of total costs for eucalyptus and poplar, and 16% for switchgrass.

The differences in the biofuel production costs for the fuel production pathways indicate the importance of using specific settings that take into account local circumstances. Implementation of a project should also depend on comparing NPVs to alternatives for selling the feedstock or cultivating other crops.

Main factors that influence the outcome of the NPV calculations are; yield, labour requirements, labour costs, land costs and the value of the by-products that are produced. High labour requirements can only be feasible with low wages, while a high level of inputs typically leads to an increased yield and therefore lower overall costs (except for jatropha).

A mayor difference between the feedstocks is the type of investment that is required for cultivation. Perennials such as Palm or Eucalyptus require several years before the first benefits can be obtained, these first years need to be overcome with other means of income. Furthermore, some annual crops such as soy, require more upfront capital investment in machinery and are therefore less suitable for small scale farmers with little income. On the other hand, there are crops that can be planted as additional (or side-) crop such as jatropha, but a reasonable income from this crop alone is unlikely. The different feedstocks should therefore be implemented in the local agricultural system according to the preferences and means of the local farmers.

The price of the commodities is a key variable for the profitability of the project. Several crops such as Palm and sugarcane have different markets they can supply, e.g. food, fuel, paper etc., sometimes even at the same time such as Soy (biodiesel and soy meal). This means the producer can choose the market with the highest price. In addition, the value of the fuel in relation to the oil price is important, in many cases this can result in good NPVs. On the other hand, the costs of biofuels will also depend on the price of the commodity in the other market, and this could also increase costs.

Local data collection and specific case studies are key to more accurate modelling of the biofuel production costs, the profitability for a farmer (by means of NPV calculations) and the identification of alternatives.

Various cost factors should be taken into consideration when analyzing the feasibility of biofuels. Costs are dynamic and long term costs should be considered indicative. Generally production costs are expected to decrease over time following continuous process improvements, technological learning and increasing scale of production. Possibilities for cost reduction can also be linked to local technology adaptation and strategies need to be developed to identify technology components that can be locally fabricated. The cost of energy sources (for example fossil diesel fuel for usage in a diesel generator in a remote village) determines the competitiveness of the biofuel and should be considered as well.

Appropriate policies need to be devised to make biofuels production more competitive and reduce investment risks. Key sustainability aspects should be fully taken into account in these policies, when assessing biofuel supply. Studies have shown that inclusion of sustainability criteria has potential impacts on the amount of biofuels that can be produced as well as final delivered costs of the biofuels (Smeets and Faaij 2010). A prerequisite is that sufficient data of high quality is available.

When the NPV is close to zero, there is an expected no-profit no loss scenario, then further research into the financial viability by an extended Cost Benefit analysis is recommended, including other indicators such as, Internal Rate of Return (IRR), Benefit / Cost Ratio (BCR) and Pay Back Period (PBP).

Given the status of the technology and investment requirements to establish processing plants, it is unlikely that large scale second generation biofuels production can be realised in developing countries in the coming decade. However, developing countries can already develop a biofuel feedstock production industry, which could be the basis for a strong biofuel industry when the technology matures. Investment in feedstock production could offer an option for developing countries to profit from the growing biomass market for second-generation biofuel production outside their borders, provided that transport infrastructure is suitably developed and key socio-economic and environmental sustainability frameworks are institutionalised. As a next step, cooperation on R&D at a scientific level, skills development and adaptation of technology would be needed in developing countries to build capacity for second-generation biofuel production. Similarly, investment strategies need to be developed and piggybacking on existing industries (such as forestry) could be one route to over-coming the project finance barriers.

Acknowledgements

This study is partly funded by the United Nations Industrial Development Organisation (UNIDO) and is part of the Targeted Research Project: Global Assessments and Guidelines for Sustainable Liquid Biofuels Production in Developing Countries which is funded by the Global Environmental Facility (GEF), United Nations Environmental Program (UNEP), Food and Agriculture Organization (FAO) and UNIDO. We would like to thank our partners IFEU (esp. Susanne Köppen and Guido Reinhardt) and OEKO institute (esp. Uwe Fritsche) and our country partners who provided valuable input data: Tetiana Zhelyezna and Olga Drozdova from Scientific Engineering Centre Biomass (SEC Biomass) in Kiev, Ukraine; Jorge Hilbert, Néstor Moris, Rodrigo Sbarra and Félix C. Martin from Instituto Nacional de Tecnologia Agropecuaria (INTA) and INTeA in Buenos Aires, Argentina, and Tereza Alves and Camila da Sousa from Instituto de Investigação Agrária de Moçambique (IIAM), in Maputo, Mozambique. Furthermore we would like to thank prof. S. Gheewala from King Mongkut's University of Technology Thonburi, Bangkok, Thailand, Alison Wright from Greenlight Indonesia, Carmen Jimenez Morales who was doing an internship at Cenipalma and Jouke Rom Colthoff. Fieldwork was executed in Mozambique in 2010 and 2012, together with Floor van der Hilst. This study was also 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 in the Seventh Framework Programme for Research and Technological Development (FP7) and was partly funded by NL Agency through the Jatropha data collection project under the Global Sustainable Biomass fund.

4.6 Appendices to Chapter 6

4.6.1 Appendix A: specification of all 74 settings

Table 4A-8: Specification of all 74 settings used in the research

No	Crop	Country	Smallholder/plantation	Management system	End product	Timeframe
1	Soy	Argentina	smallholders	low mechanisation, no tillage	SVO	2010
2	Soy	Argentina	smallholders	no mechanisation, no tillage	FAME	2010
3	Soy	Argentina	plantation	high rate of mechanisation, tillage	FAME	2010
4	Soy	Argentina	plantation	high rate of mechanisation, no tillage	FAME	2010
5	Soy	Argentina	plantation	high inputs (irrigation), no tillage	FAME	2020
6	Soy	Argentina	plantation	high rate of mechanisation, tillage	FAME	2020
7	Soy	Argentina	plantation	high rate of mechanisation, no tillage	FAME	2020
8	Sugarcane	Brazil	centralised system (with outgrowers)	mechanisited harvesting, no irrigation (intermediate inputs)	EtOH	2010
9	Sugarcane	Brazil	centralised system (with outgrowers)	manual harvesting, irrigation (high inputs)	EtOH	2010
10	Sugarcane	Brazil	centralised system (with outgrowers)	mechanised harvesting, irrigation	Next EtOH	2020
11	Sugarcane	Mozambique	centralised system (with outgrowers)	no irrigation (intermediate inputs)	EtOH	2010
12	Sugarcane	Mozambique	centralised system (with outgrowers)	irrigation (high inputs)	EtOH	2010
13	Sugarcane	Brazil	centralised system (with outgrowers)	mechanised harvesting, no irrigation (intermediate inputs)	EtOH	2020
14	Sugarcane	Brazil	centralised system (with outgrowers)	mechanised harvesting, irrigation (high inputs, high rate mechanisation)	EtOH	2020
15	Sugarcane	Brazil	centralised system (with outgrowers)	mechanised harvesting, irrigation (high inputs, high rate mechanisation)	Next EtOH	2030
16	Sugarcane	Mozambique	centralised system (with outgrowers)	no irrigation (intermediate inputs)	EtOH	2020
17	Sugarcane	Mozambique	centralised system (with outgrowers)	irrigation (high inputs)	EtOH	2020
18	Palm	Indonesia	smallholders	intermediate inputs	SVO	2010
19	Palm	Indonesia	smallholders	intermediate inputs	FAME	2010
20	Palm	Indonesia	plantation	high inputs	FAME	2010
21	Palm	Colombia	smallholders	intermediate inputs	FAME	2010

22	Palm	Malaysia	plantation	high inputs	FAME	2010
23	Palm	Indonesia	plantation	high inputs	FAME	2020
24	Palm	Malaysia	plantation	high inputs	FAME	2020
25	Jatropha	Tanzania	smallholders	low inputs, marginal land, no irrigation	SVO	2010
26	Jatropha	Tanzania	plantation	high inputs, good land, no irrigation	FAME	2010
27	Jatropha	Tanzania	plantation	intermediate inputs, marginal land, no irrigation	FAME	2010
28	Jatropha	Tanzania	smallholders	low inputs, marginal land, no irrigation	FAME	2010
29	Jatropha	Tanzania	smallholders	smallholder, intermediate inputs, marginal land	FAME	2010
30	Jatropha	Mali	smallholders	low inputs	FAME	2010
31	Jatropha	Mali	smallholders	intermediate inputs	FAME	2010
32	Jatropha	India	smallholders	low inputs	FAME	2010
33	Jatropha	India	smallholders	intermediate inputs	FAME	2010
34	Jatropha	Tanzania	plantation	high inputs, good land, no irrigation	FAME	2020
35	Jatropha	Tanzania	plantation	intermediate, marginal land, no irrigation	FAME	2020
36	Jatropha	Tanzania	smallholders	low inputs, marginal land	FAME	2020
37	Jatropha	Tanzania	smallholders	intermediate inputs, marginal land	FAME	2020
38	Jatropha	Mali	smallholders	low inputs	FAME	2020
39	Jatropha	Mali	smallholders	intermediate inputs	FAME	2020
40	Jatropha	India	smallholders	low inputs	FAME	2020
41	Jatropha	India	smallholders	intermediate inputs	FAME	2020
42	Cassava	Mozambique	smallholders	low inputs (see table for definition)	EtOH	2010
43	Cassava	Mozambique	smallholders	intermediate inputs	EtOH	2010
44	Cassava	Tanzania	smallholders	low inputs	EtOH	2010
45	Cassava	Tanzania	smallholders	intermediate inputs	EtOH	2010
46	Cassava	Thailand	smallholders	low inputs	EtOH	2010
47	Cassava	Thailand	smallholders	intermediate inputs	EtOH	2010
48	Cassava	Mozambique	smallholders	low inputs	EtOH	2020
49	Cassava	Mozambique	smallholders	intermediate inputs	EtOH	2020
50	Cassava	Mozambique	plantation	high inputs	EtOH	2020
51	Cassava	Tanzania	smallholders	low inputs	EtOH	2020
52	Cassava	Tanzania	smallholders	intermediate inputs	EtOH	2020
53	Cassava	Tanzania	plantation	high inputs	EtOH	2020
54	Cassava	Thailand	smallholders	low inputs	EtOH	2020
55	Cassava	Thailand	smallholders	intermediate inputs	EtOH	2020
56	Cassava	Thailand	plantation	high inputs	EtOH	2020
57	SRC Eucalyptus	Mozambique	plantation	less suitable land, well managed plantation, no irrigation	next EtOH	2020
	SRC Eucalyptus	Mozambique	plantation	less suitable land, well managed plantation, no irrigation	solid	
58	SRC Eucalyptus	Brazil	plantation	less suitable land, well managed plantation, no irrigation	Next EtOH	2020

59	SRC Eucalyptus	Brazil	plantation	suitable land, well managed plantation, no irrigation	Next EtOH	2020
60	SRC Eucalyptus	Mozambique	plantation	less suitable land, well managed plantation, no irrigation	Next EtOH	2030
61	SRC Eucalyptus	Brazil	plantation	less suitable land, well managed plantation, no irrigation	Next EtOH	2030
62	SRC Eucalyptus	Brazil	plantation	suitable land, well managed plantation, no irrigation	Next EtOH	2030
63	SRC poplar	Ukraine	plantation	less suitable, well managed plantation, no irrigation	BTL	2020
64	SRC poplar	Ukraine	plantation	suitable, well managed plantation, no irrigation	BTL	2020
65	SRC poplar	Ukraine	plantation	less suitable, well managed plantation, no irrigation	BTL	2030
66	SRC poplar	Ukraine	plantation	suitable, well managed plantation, no irrigation	BTL	2030
67	Switchgrass	Argentina	plantation	less suitable land, well managed plantation, no irrigation	Next EtOH	2020
68	Switchgrass	Argentina	plantation	less suitable land, well managed plantation, no irrigation	BTL	2020
69	Switchgrass	Argentina	plantation	less suitable land, well managed plantation, no irrigation	Next EtOH	2030
70	Switchgrass	Argentina	plantation	less suitable land, well managed plantation, no irrigation	BTL	2030
71	Rice straw	China			Next EtOH	2020
72	Wheat straw	Ukraine			Next EtOH	2020
73	Rice straw	China			Next EtOH	2030
74	Wheat straw	Ukraine			Next EtOH	2030

4.6.2 Appendix B: Input data

4.6.2.1 B1: Input data for Soy

Table 4B-9: Input data used in calculations soy settings 1-7

Country	Unit	Argentina	Argentina	Argentina	Argentina	Argentina	Argentina	Argentina	Source
Setting No.		1	2	3	4	5	6	7	
System		Smallholders	Smallholders	Plantation	Plantation	Plantation	Plantation	Plantation	
Mechanisation		low	low	high	high	high (irrigation)	high	high	
Tillage		no	no	yes	no	no	yes	no	
Endproduct		SVO	FAME	FAME	FAME	FAME	FAME	FAME	
Year		2010	2010	2010	2010	2020	2020	2020	
Yield	t/ha	2.8	2.8	3.6	4.5	4	4	5	(INTA 2011b)
Province		South of Cordoba (rio Cuarto)	South of Cordoba (rio Cuarto)	Pergamino and Pehuajo (North and West of BA)	South of Santa Fe (Venado Tuerto)				
t dry per ton fresh		0.865	0.865	0.865	0.865	0.865	0.865	0.865	
Yield dry	T (dry)/ha	2.51	2.42	3.11	3.89	3.46	3.46	4.33	
Transport distance field-processing unit	km	400	400	140	190	140	140	190	(INTA 2011b)
Transport distance SVO to filling station	km	150	150	150	150	150	150	150	Est. IFEU
Discount factor		8.2	8.2	8.2	8.2	8.2	8.2	8.2	(Van Eijck et al. 2012)
Price soy beans	US$/ton	168.82	168.82	168.82	168.82	168.82	168.82	168.82	(INTA 2011b)
Transport costs	US$/ton km	$0.06	$0.06	$0.06	$0.06	$0.06	$0.06	$0.06	(van Dam et al. 2009a)
crushing	US$/ton grain	$12	$12	$12	$12	$5	$5	$5	(van Dam et al. 2009a)
Allocation to oil	%	20%	20%	20%	20%	20%	20%	20%	

Density	Ton/liter	0.000892	0.000892	0.,000892	0.000892	0.000892	0.000892	0.000892	"
Energy content biodiesel	GJ/l	0.032728							
Conversion costs biodiesel	US$/l	$0.00	$0.12	$0.12	$0.12	$0.12	$0.12	$0.12	"
wage rate	US$/hour	$3.18	$3.18	$3.18	$3.18	$8.29	$8.29	$8.29	"
ton grains per ton oil		5.897	5.897	5.897	5.897	5.897	5.897	5.897	"
Seeds	US$/ha	$32.64	$32.64	$45.70	$45.70	$45.70	$45.70	$45.70	"
Herbicides	US$/ha	$93.66	$93.66	$113.87	$113.87	$113.87	$113.87	$113.87	"
Insecticides	US$/ha	$50.10	$50.10	$75.50	$75.50	$75.50	$75.50	$75.50	"
Fertilizers	US$/ha	$29.7	$29.7	$102.60	$102.60	$102.60	$102.60	$102.60	"
	US$/ha	$3.00	$3.00	$3.00	$3.00	$3.00	$3.00	$3.00	"
Labour input	US$/ha	$4.87	$4.87	$2.83	$2.83	$7.24	$7.24	$7.21	"
Fuel input	US$/ha	$8.21	$8.21	$13.30	$13.30	$13.30	$13.30	$13.57	"
O&M	US$/ha	$9.71	$9.71	$11.74	$11.74	$11.74	$11.74	$11.74	"
Harvesting costs	US$/ha	$43.20	$41.71	$43.20	$43.74	$43.74	$43.74	$54.68	"

4.6.2.2 B2: Input data for Sugarcane

Table 4B-10: Input data used in calculations for sugarcane settings 8-17

Setting number	unit	8	9	10	11	12	13	14	15	16	17	source
Country		Brazil	Brazil	Brazil	Mz	Mz	Brazil	Brazil	Brazil	Mz	Mz	
Year		2010	2010	2020	2010	2010	2020	2020	2030	2020	2020	
Yield	Kg/ha	60	90	90	76	100	63	94.5	94.5	79.8	105	(De Vries et al. 2012; van der Hilst and Faaij 2012; Herreras Martínez et al. 2013b)
Sugarcane field to ethanol factory	km	50	50	50	50	50	50	50	50	50	50	IFEU est (Franke et al. 2012)
Ehtanol factory to filling station	km	200	200	200	200	200	200	200	200	200	200	IFEU est. (Franke et al. 2012)
Transport costs	$/ton km	0.035	0.035	0.035	0.096	0.096	0.035	0.035	0.035	0.096	0.096	(CEPAGRI et al. 2011; Herreras Martínez et al. 2013a)
Conversion to ethanol	$/m^3	164.27	164.27	164.27	164.27	164.27	113	113	113	113	113	(van den Wall Bake et al. 2009)

Land rent	$/ha				22	22				22	22	(van der Hilst and Faaij 2012)
Land clearing	$/ha				1350	1350				1350	1350	(van der Hilst and Faaij 2012)
Planting												
Seeds	$/ha				357	357				357	357	(Xhinavane mill 2010)
land preparation	$/ha				398	398				398	398	
cultivation labour	$/ha				27	27				27	27	
cultivation chemicals	$/ha				115	115				115	115	
cultivation fertiliser	$/ha				231	231				231	231	
cultivation mechanized	$/ha				150	150				150	150	
Ratoon cultivation												(Xhinavane mill 2010)
Labour	$/ha				248	248				248	248	
Pesticide/Herbicide	$/ha				115	115				115	115	
Fertiliser	$/ha				219	219				219	219	
Mechanized (tractors, ripeners)	$/ha				194	194				194	194	
Irrigation	$/ha				0	604				604	604	(van der Hilst and Faaij 2012)
instalment	$/ha				0	2697				2697	2697	
Labour	$/ha				0	182				182	182	
Maintenance	$/ha				0	106				106	106	
Electricity	$/ha				0	245				245	245	
Bulk Supply	$/ha				0	72				72	72	
Harvest and delivery												
harvest	$/ton				9	9				9	9	(Xhinavane mill 2010)
Market price sugarcane	$/ton				35	35				35	35	(Jelsma et al. 2010)

Note: all data for Brazil is based on (Herreras Martínez et al. 2013a). (all $ are US$$_{2010}$)

4.6.2.3 B3: Input data for Palm

Table 4B-11: Input data used in calculations for palm oil settings 18-24

Country	Unit	Indonesia	Indonesia	Indonesia	Colombia	Malaysia	Indonesia	Malaysia	Colombia	Source
Setting nr		18	19	20	21	22	23	24	21b	
Endproduct		SVO	FAME	FAME	FAME	FAME	FAME	FAME	FAME	
Year		2010	2010	2010	2010	2010	2020	2020	2020	
Yield FFB	t/ha	16	16	17	18	19	19	19	19	IFEU/UU
Transport plantation to mill	km	7	75	75	75	75	75	75		(Global Biopact 2011)
mill to refinery	km	200	200	200	200	200	200	200		
refinery to end user	km	200	200	200	200	200	200	200		
kg FFB's per litre SVO (OER)		4.76			4.76					
Price FFB	$/kg	$0.15	$0.15	$0.15						(Fedepalma 2010b)
Price FFB	$/ton	$152.97	$152.97	$152.97	$152.97	$60.17				(Ismail et al. 2003; Fedepalma 2010b)
Transport costs FFB	$/ton km	$2.24	$2.24	$2.24	$0.11					(Ministerio de Transporte 2003; Global Biopact 2011)
Transport costs oil	$/ton km				$0.06					_ENREF_21(Ministerio de Transporte 2003)
Production CPO per ton	$/ton				35.23					
Refining and esterification	$/l		0.20	0.20	0.20	0.20	0.02	0.02	0.20	
Wages agricultural sector	$/day	$3	$3	$3	$7		$3			Laboursta
Exchange rates		IDR 8.910			CLP 1.966	MYR 3,13	IDR 8.910			www.oanda.com

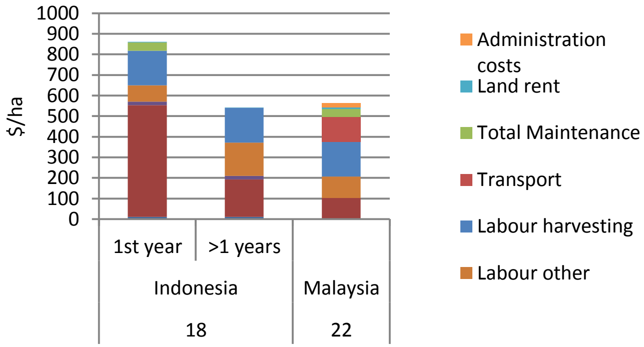


Figure 4B-23: Input data palm FFB production in Indonesia and Malaysia (Ismail et al. 2003; Global Biopact 2011)

Table 4B-12: Input data for setting 21, palm production in Colombia in discounted $/ha (Fedepalma 2010b)

	21
	Colombia
Total inputs	$5.797
Seed / Seedlings	$300
Fertilizers	$4.633
Phytosanitary control	$74
Weed control	$50
other Supplies	$740
Total Labour	$3.122
Nursery and planting	$74
Fertilization	$198
Phytosanitary control	$360
Weed control	$508

Harvest	$1.847
Other activities	$134
Transport	$522
Total Maintenance	$1.263
equipment	$271
animals	$77
infrastructure	$915
Total Fixed Capital	$2.410
Land rent	$0
Administration costs	$1.580
TOTAL	$14.693

4.6.2.4 B4: Input data for Jatropha

Table 4B-13: Input data used in calculations for jatropha settings 25-41 (the settings 25-33 are shown in detail, the settings 34-41 are all based on 2020 and are similar unless noted otherwise)

Setting number	Unit	25	26	27	28	29	30	31	32	33	34-41	source
Country		Tanzania	Tanzania	Tanzania	Tanzania	Tanzania	Mali	Mali	India	India	2020	
Yield	Kg/ha	1100	3000	2500	1100	1980	1000	1500	2000	2500	+15%	
Land rent	US$	20	20	20	20	20	0	0	$19.92	$19.92		(Estrin 2009; Baxter 2011b; Van Eijck et al. 2012)
market price	$/kg	$0.14	$0.14	$0.14	$0.14	$0.14	$0.11	$0.11	$0.19	$0.19		
wage rate	$/day	$2.00	$2.00	$2.00	$2.00	$2.00	$2.46	$2.46	$1.29	$1.29		
Harvest efficiency	Kg/person/ day	40	40	40	40	40	40	40	40	40		
Conversion costs	$/l	$0.20	$0.20	$0.20	$0.20	$0.20	$0.20	$0.20	$0.14	$0.14	$0.02	
Distribution costs	$/l	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01	
Transport from field to	km	450	190	190	450	450	450	450	450	450		

processing unit												
Transport from processing to filling station	km	200	200	200	200	200	200	200	200	200		
price per km (10t)	$/ ton km	$0.096	$0.096	$0.096	$0.096	$0.096	$0.096	$0.096	$0.030	$0.030		

Data Tanzania: (Van Eijck et al. 2012) , (Van Eijck 2009) (conversion -0,03 $/l due to glycerine sales)

Data Mali: (Pallière and Fauveaud 2009), land: (Baxter 2011b), Wages: (API Mali 2010), market prices seed: personal communication Ard Lengkeek (Mali Biocarburant)

Data India: (Estrin 2009) (Altenburg et al. 2009)

Labour requirements for Jatropha cultivation and inputs and costs are based on (Van Eijck et al. 2012). Transesterification costs are 0.25 $/l for the 2010 settings based on Van Eijck et al. (2012), and 0.15 $/l for the settings in 2020, based on Mulugetta (2009). Land rent is 20 $ per ha per year.

4.6.2.5 B5: Input data for cassava

Table 4B-14: Yield levels for cassava

Setting number	Input system	Yield (t/ha)	Region	Literature source
42	Low inputs	4	Mozambique	FAO average
43	Intermediate inputs	6	Mozambique	FAO average
44	Low inputs	6	Tanzania	(Van Eijck et al. 2012)
45	Intermediate inputs	12	Tanzania	(Van Eijck et al. 2012)
46	Low inputs	20	Thailand	(Office of Agricultural Economics (OAE) 2009)*
47	Intermediate	22	Thailand	(Office of Agricultural Economics (OAE) 2009)* average of country averages 2007-2009
54	Low	32	Thailand	(Silalertruksa and Gheewala 2010)*
55	Intermediate	34	Thailand	(Silalertruksa and Gheewala 2010)*
56	High	44	Thailand	Estimate IFEU/UU

* also based on personal communication Prof. Gheewala, Bangkok, Thailand

Table 4B-15: Input data used in calculations for cassava settings 42-56 (the settings 42-47 are shown in detail, the settings 48-56 are all based on 2020 and are similar unless noted otherwise)

Country	Unit	Mozambique	Mozambique	Tanzania	Tanzania	Thailand	Thailand	
Setting nr		42	43	44	45	46	47	48-56
System		Smallholders	Smallholders	Smallholders	Smallholders	Smallholders	Smallholders	
Inputs		low	intermediate	low	intermediate	low	intermediate	
Year		2010	2010	2010	2010	2010	2010	2020
Yield	t/ha	4	6	6	12	20	22	
Transport distance field-chips	km	10	10	10	10	10	10	
Transport distance chips-ethanol	km	100	100	100	100	100	100	1
Transport distance ethanol-distribution	km	200	200	200	200	200	200	

Discount factor	%	8.20%	8.20%	8.20%	8.20%	8.20%	8.20%	
kg roots per litre ethanol	Kg/l	7.5	7,5	7,5	7,5	7,5	7.5	
average wage in agricultural sector	$/day	2	2	2,00	2	3,3-4,3	3,3-4,3	$4,00
Price fresh roots	$/ton	$58	$58	$91	$91	$45	$45	
Transport costs	$/ton km	0.096						
COSTS								
Land preparation	$/ha	$60	$60	$60	$60	70	$70	
Plantation	$/ha	$58	$58	$58	$58	32	$32	
Treatment	$/ha	$62	$108	$62	$108	41	$81	
Harvesting	$/ha	$104	$104	$104	$104	91	$91	
Labour costs	$/ha	284	330	284	330	233	$233	
Varieties/stakes	$/ha	$10	$10	$10	$10	$42	$42	
Fertilizers	$/ha		$52		$52	$33	$675	
Herbicide & Insecticide	$/ha		$21		$21	$16	$32	
Fuels and lubricant	$/ha					$0.72	$1.44	
Agricultural materials and auxilliaries	$/ha	$18	$18	$18	$18	$0.46	$0.93	
Maintenance costs	$/ha					$0.31	$0.31	
Material cost	$/ha	$28	$101	$28	$101	$93	$93	
Interest						$32	$32	
Land rental costs	$/ha	$20	$20	$20	$20	$57	$57	
Depreciation costs for agricultural machines	$/ha					$1.65	$1.65	
Interest for agricultural machinery	$/ha					$0.21	$0.21	
Fixed costs	$/ha					$59	$59	
TOTAL	$/ha	$48	$121	$48	$121	$184	$184	
TOTAL incl Labour	$/ha	**$332**	**$451**	**$332**	**$451**	**$417**	**$417**	

4.6.3 Appendix C : Second generation biofuels

4.6.3.1 Feedstock production and supply

The development of second generation energy crop plantations involves four major phases: site preparation, planting, maintenance and harvesting. Specific activities at each stage depend on the site quality which influences the degree of site preparation that is necessary; choice of species, planting density, and rotations; required cultural management and soil amendments (fertilisation, weed control, animal control, and pest management); as well as transport and logistics.

Eucalyptus production costs in Brazil and Mozambique: Table 4C-16 shows the eucalyptus production cost inputs in Mozambique

Table 4C-16: Cost elements for eucalyptus production in Mozambique

Cost Item	Description
Land	Costs of land vary between 20 $/ha/yr (2009) for agricultural land uses depending on locations (CPI, 2009).
Labour	Minimum wage is 0.3 $/hr in the agricultural sector
Diesel	36 litres per ha at cost of 1.02 $/litre
Seeds	1,333 plants per ha at cost of 0.20 $/plant
Herbicides	3 litres/ha at costs of 2.23 $/litre
Pesticide	0,1 kg/ha of fungicides and 0.6 litres/ha of pesticides at average cost of 9.55 $/litre
NPK	60 kg/ha of N fertiliser, 23 kg/ha of P fertiliser and 48 kg/ha of K fertiliser at average cost of 0.77 $/kg

Source: (Laclau et al. 2003; Chemonics and IFDC 2007; van der Hilst and Faaij 2012)

Future changes in feedstock production cost - Long term pressure on land is expected under a business as usual scenario and thus the cost for land is likely to increase, pushing up biomass production costs. Similarly, as Mozambique's economy grows, it is expected that labour wages will increase. When labour costs increase, efficient machinery will become more attractive. Energy input costs are also expected to grow, but with improving infrastructure, diesel distribution costs could go down. When diesel prices go up, full mechanisation will be less attractive. In the future, improved seeds and breeding as well as technological learning about seed technology are expected to result in higher biomass yields which will result in decreasing production costs. Globally, fertiliser prices will increase due to higher fossil fuel prices and to P fertiliser scarcity. Locally, prices could go down when there is critical mass for the establishment of domestic production. All these factors are expected to have varied impacts on the biomass production costs, but increase in yields is likely to have a much bigger impact on overall costs - and thus future costs are expected to decrease.

Eucalyptus production costs in Brazil -- For Brazil, eucalyptus production costs are estimated using a set of assumptions shown in Table 4C-18. For the different soil qualities, the required amount of fertiliser and corresponding biomass yields are shown in Table 4C-17.

Table 4C-17: Fertiliser requirements for eucalyptus production in Brazil by land suitability

Required fertiliser amounts (kg/ha)	Suitable	Less suitable
NH_4	83	60
P_2O_5	32	23
K_2O	67	48
CaO	97	70
Total	279	201

Table 4C-18: Value of cost item for eucalyptus production in Brazil

Cost Item	Value	Unit	Source
Wages-Field workers	2.87-7.74	$/h	calculated
Tractor	13.13	$/h	(WSRG 2004)
Fencing -material and machinery	439.17	$/ha	(Faúndez 2003)
Plant costs	0.07	$/plant	various, own calculations
Herbicides	126	$/ha	(Faúndez 2003)
Fertilisers	68.6-207.2	$/ha	various, own calculations
Pesticides Chemicals	8.4	$/ha	(Faúndez 2003)
Fungicides Chemicals	4.2	$/ha	(Faúndez 2003)
Land rent	49-145.6	$/ha	World Bank
Harvester[1]	494	k$/machine	(Picchio et al. 2012)
Harvesters - loader[2]	165	k$/machine	(Picchio et al. 2012)

[1]: 173 kW John Deere 1270C harvester with a felling processing head JD 762 C for felling and bunching trees.
[2]: 132 kW Forest loader OP T80 to assist harvester in tree bunching

Poplar production costs in Ukraine: Table 4C-19 shows the corresponding amounts of input requirements by land suitability.

Table 4C-19: Poplar SRC yields and fertiliser inputs in Ukraine by land suitability classes

	Suitable	Marginally suitable
Yield (tdm $ha^{-1}yr^{-1}$)	14	6
NH4 input (kg/ha)	71	34
P2O5 input (kg/ha)	20	10
K2O input (kg/ha)	52	24
Manure (organic fertiliser equivalent*) (tons/ha)	20	11

* According to SEC Biomass (2011) manure is used instead of chemical fertilisers and estimates are based on a range of 11-40 tons per hectare. Equivalent chemical fertilisers are estimated by (Smeets and Faaij 2010).

Switchgrass production costs in Argentina: Table 4C-20 shows the input requirements for switchgrass production in Argentina in 2020 and 2030.

Table 4C-20: Cost assumptions of key switchgrass production inputs in Argentina (van Dam et al. 2009a)

Item	2020	2030	Units
Land rent	110	110	$/ha/yr
Seeding input	22.5	22.5	$/ha
Fertiliser input	12.0	49.5	$/ha
Herbicides input	2.85	6.41	$/ha
Labour costs	295.87	552.04	$/ha
Fixed costs machinery	1,964	2,015	$/ha
Fuel costs	493.11	688.30	$/ha
Aggregate costs	306	373	$/ha

Rice and wheat straw production: Table 4C-21 shows the cost estimates for wheat straw collection and packaging in a typical Ukrainian facility.

Table 4C-21: Cost estimates of wheat straw collecting and packaging in Ukraine (SEC Biomass 2011)

Straw harvesting activity	**Tractor**		**Fuel**		**Labour**	
	$/ha	$/hr	$/ha	$/hr	$/ha	$/hr
Cutting and raking	35	97	35	100	0.4	1
Baling (square baler + tractor) Bales 30kg	20	33	14.5	25.2	0.58	1
Forwarding to roadside (500m)/baler pick up (tractor front end loaders)	20	40	10	22	0.48	1

4.6.3.2 Second generation biofuels - supply chain analysis

Biomass energy supply chains start with the feedstock production until final biomass fuel is delivered in the market. The number of intermediate stages in a chain varies depending on the feedstock characteristics, pretreatment requirements and infrastructure. More detailed discussion on second generation bioenergy supply chains is given in Batidzirai et al. (2013). Biofuel production costs include feedstock production costs, pretreatment costs, transport costs, storage costs and conversion costs. The costs that are analysed here are very generic, in the sense that it is important to include spatial detail and biomass distribution detail to come up with more representative estimates. However, country specific information is also included, such as expected transport distances and truck transport limitations as well feedstock production costs. See Table 4C-22.

Table 4C-22: Key assumptions for biomass transportation in selected countries

	Mozambique	Brazil	Ukraine	Argentina/China
Distance from farm to conversion plant (km)	100	200	50	120
Truck capacities (tons)	20	40	40	40

5 Global experience with jatropha cultivation for bioenergy: an assessment of socio-economic and environmental aspects

JANSKE VAN EIJCK, HENNY ROMIJN, ANNELIES BALKEMA, and ANDRÉ FAAIJ

Renewable and Sustainable Energy Reviews (2014) 32, 869-889[16]

Abstract

This is an assessment of key economic, environmental and social issues pertaining to jatropha biofuels, based on almost 150 studies covering 26 countries. The assessment aims to furnish a state-of-the-art overview and identify knowledge gaps. So far, total jatropha production has remained small. Numbers and value of jatropha projects have even declined since 2008.

The economic analyses indicate minimal financial feasibility for projects. Yield increase and value addition (e.g., through utilising by-products) are necessary. Plantations seem to fare the worst, mainly due to the higher financial inputs used in a plantation setting and the still limited yield levels. Smallholders can only achieve financial feasibility in low-input settings and when opportunity costs are low. Unfortunately, hardly any Cost Benefit Analyses (CBA) are based on real data; partly due to a lack of long-running jatropha projects.

The environmental impact varies greatly across locations. Most studies indicate significant greenhouse gas (GHG) benefits over fossil fuels; however, this is only achieved with limited inputs and no loss of high C-stock biodiversity. The determinants in Life Cycle Analyses (LCA) are yield, input level, by-products utilization, transesterification, transport distances, and land cover. More LCA research is required with more accurate data, and focusing on nitrous oxide emissions and the relation between production intensity and biodiversity impacts.

Minimal negative social impacts have been revealed so far, but discontinuation of projects affects communities through income losses and fostering more negative attitudes towards new projects. Moreover, hardly any studies quantify social impact comprehensively. Detailed data collection is necessary, involving baseline studies to start with. If its financial feasibility is improved, jatropha can still become an option for sustainable energy production, GHG mitigation and rural development, especially through smallholder models. Successful implementation requires careful advance assessment of local circumstances, such as the political climate, gender aspects and land ownership structures.

[16] This chapter is based on research funded by NL Agency and and by the Responsible Innovation research programme of the Netherlands Science Organisation (NWO).

5.1 Introduction

Jatropha (*Jatropha curcas* L.) is being promoted as a potential renewable energy source as the tropical woody perennial tree or shrub species may survive in harsh climate and soil conditions. The current potential for producing jatropha biodiesel in arid and semi-arid areas in eight countries in Sub-Saharan Africa can be as large as 600 PJ yr^{-1} (Wicke et al. 2011). Furthermore, it is listed by the IPCC[17] as one of the potential bioenergy crops, with estimated costs of around 3.2 US$ GJ^{-1} (Chum et al. 2011). However, there is insufficient knowledge about some of the agronomic, socio-economic and technical aspects of the jatropha value chain and its implications for the sustainable livelihoods of local communities. Despite these uncertainties, large numbers of projects on different scales and with varying objectives have been implemented to develop viable bioenergy cropping systems. A study by GEXSI identified 242 projects in 55 countries (GEXSI 2008). In 2008, this study projected that the total global area under jatropha cultivation would grow to 5 million ha in 2010. This was at a time when jatropha was receiving a great deal of attention and this projection raised high expectations. Later studies lowered the expectations, for example Achten et al. (2010) and GTZ (2009b), or were even quite negative, such as Kant and Wu (2011). At the same time socio-economic and environmental sustainability issues for biofuels were becoming more important, as evidenced by, for example, the formulation of criteria by both the Roundtable on Sustainable Biofuels (RSB) and the Global Bioenergy Partnership (GBEP) (GBEP 2009).

The focus on the viability and sustainability of jatropha as an energy crop has led to an increasing number of research publications, project results and experiences of different aspects of the jatropha value chain in various reports. These publications focus on different aspects, for example on cultivation (Jongschaap et al. 2007; Gordon-Maclean et al. 2008; Loos 2008), processing and technical properties (Vyas and Singh 2007; Makkar et al. 2008; Lestari et al. 2010; Koh and Mohd. Ghazi 2011; Ong et al. 2011), market prospects (Hardman&Co 2011), and the impact on the environment (Finco and Doppler 2010; Bailis and McCarthy 2011). In addition, different business models and impacts on farming systems have been assessed (Mota 2009; Van Eijck et al. 2013), as well as the impact of the policy environment (Schut et al. 2010a). Some publications describe a certain aspect of the value chain, whereas others focus on a specific country (such as Mshandete, (2011), and Liu et al., (2012), focusing on Tanzania and China, respectively) or on one business model (for example Brittaine and Lutaladio, (2010), who focused on smallholders). Furthermore, Carels (2009) published a review including agronomical and

[17] Intergovernmental Panel on Climate Change

technological aspects, while Abdulla et al. (2011) compiled a review on technical issues only. In addition to being heterogeneous, a large share of the literature is based on secondary sources that are not necessarily accurate and lag behind the fast-changing realities on the ground. The jatropha sector is dynamic: many new projects are starting up while others are being discontinued. Both successes and failures could provide valuable lessons if analysed systematically.

The objective of this chapter is to provide a comprehensive overview of recent literature based on information from ongoing and discontinued jatropha projects, which analyses the lessons learned so far and identifies knowledge gaps by evaluating and screening against generally agreed socio-economic and environmental sustainability criteria. Although agronomy and technology are important aspects in jatropha cultivation and processing, these aspects are not part of a sustainability framework such as RSB or GBEP. However, they are essential for increasing the efficiency of the cropping system and thus the various impacts. Several studies have taken the technical aspects into account, such as Silitonga et al. (2011) and Shahid and Jamal (2011). The main conclusion from these studies was that it is technically possible to use jatropha biofuel in diesel engines. However, more research is required to gain better insight into the lifetime of the engine. The agronomic aspects are currently being studied in long-term projects such as (JATROPT 2010) and (Quinvita 2011). Knowledge gaps on agronomy issues are reviewed in (Van Eijck et al. 2010).

This chapter starts with an overview of the global jatropha sector; subsequently, the aspects included in the review are discussed (Section 5.3). Section 5.4 presents an overview of the studies used and Section 5.5 provides details on the analysis of these studies. Knowledge gaps are identified in Section 5.6 and lastly conclusions (Section 5.7) and recommendations (Section 5.8) are provided. Throughout this assessment, the term *jatropha oil* is used for both jatropha biodiesel and jatropha Straight Vegetable Oil (SVO); some studies refer to jatropha biodiesel as Jatropha Methyl Ester (JME).

5.2 Status of jatropha projects / overview of the sector

In 2008, 242 jatropha projects were identified as carried out or about to be carried out, around the world. These were both small-scale projects for local energy production and large-scale projects aimed either at establishing a national supply base or at production for export. Not all projects have received the same amount of publicity in the literature. There are also numerous jatropha projects that either have not yet started their operations, despite persistent publicity, or have had to scale down or even close down operations without adequate reporting. Therefore, in addition to literature sources, numerous field visits, contacts with project managers, and interviews with employees took place over the period 2006-2012 to compile this chapter. Based on these sources, Figure 5-1 presents the countries with ongoing jatropha projects.

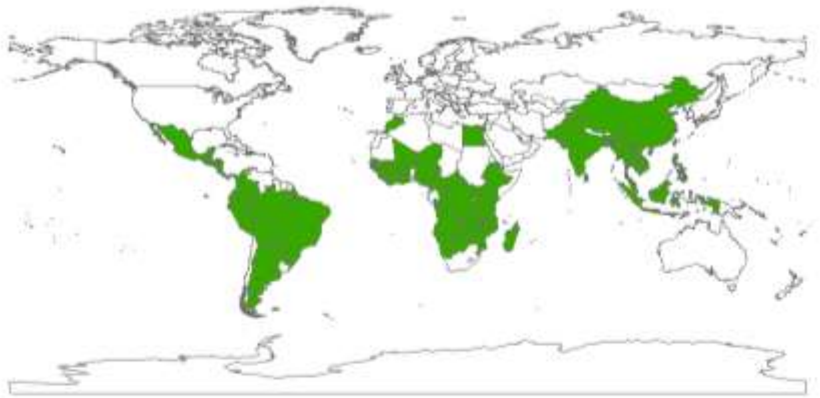


Figure 5-1: Countries where jatropha activities have been reported
Sources: based on (GEXSI 2008), (van Peer 2011), (Silitonga et al. 2011) and fieldwork. Note: Russia was not taken into account in the GEXSI study.

A large number of jatropha projects have been implemented in Asia (India and Indonesia), Africa (East and West) and Latin America (Mexico, Brazil). Although many of them have ceased (part of) their operations. This is confirmed by (2011) and (2012), who mentioned that the main countries with current jatropha activities are India, Indonesia, Mozambique, Tanzania, Madagascar, Mexico and Brazil. The majority of the amount of ha planted is found in Asia (85%) and Africa (13%) while only 2% is reported to have been planted in Latin America, according to the study by GESXI (GEXSI 2008). Different business models and scales are being applied, from smallholder models with a centralised processing unit, participatory village systems aiming for rural electrification and soil conservation to large-scale centralised plantations. Some large-scale plantations received bad publicity and some had to shut down due to cashflow problems, e.g. in Tanzania, Mozambique and the Philippines (BioShape, Energem, Sun Biofuels) (Mutch 2010; Wa Simbeye 2010; Flores 2011; Wa Simbeye 2011c). Unjustified high yield expectations are often at the basis of these cashflow problems. Furthermore, 4 out of 5 jatropha investments listed and analysed by Hardman & Co have seen a decline in value, the largest drop noted by D1 oils which went from 32 m£ at listing to 4.6 m£ in February 2011 (Hawkings and Chen 2011). In addition to high yield expectations, the decline in value is caused by losses on investments in biofuel refinery capacity and by an unfavourable location of the jatropha plantations. On the other hand, the aviation industry has shown an interest in utilising jatropha oil as jet fuel. Several test flights have been performed, for example in 2008 by Air New Zealand in cooperation with Boeing and Continental airlines, and later with China Airlines (Biofuels international 2011; Hawkings and Chen 2011). Still, so far the volume of jatropha oil in the total of consumed aviation fuels has remained relatively small (50,000 l jatropha oil was consumed by the Air New Zealand flight), not exceeding a few hundred thousand litres. Currently some pilot projects are being executed that attempt to certify jatropha production under a sustainability certification scheme (Fair Trade, NTA8080 and RSB). This could help to separate sustainable practices from unsustainable ones.

There are also several on-going research projects (Hawkins and Chen 2012). For example, there is a project at Leuphana University in Germany, where researchers are compiling an overview to assess the current and future production potential of sustainable fuels, including jatropha (Leuphana 2011). As mentioned above, there are long-term studies on agronomic issues (JATROPT 2010; Quinvita 2011), and there are research projects on socio-economic and sustainability issues by several NGOs (e.g. HIVOS, ActionAid) and research institutes such as Utrecht University, Eindhoven University of Technology, Plant Research International and Leuven University. In addition, Groningen University and the University of Hohenheim are two of the institutes that are currently assessing technical issues. Many of the jatropha projects that have been initiated in the last five years have been discontinued or have slowed down their pace of implementation. This makes it hard to collect data and consider the long-term impact. The data used in this assessment are based as much as possible on projects that were actually executed; however, some of these projects have been discontinued since then. Nevertheless, we can still learn some valuable lessons from these projects.

5.3 Review methodology and issues covered

The analysis of the studies was based on the common core sustainability principles and criteria formulated by various working groups (e.g. RSB and GBEP) and the Cramer criteria (Projectgroep Duurzame productie van biomassa 2006; GBEP 2009; RSB 2009b; RSB 2010; van Dam et al. 2010b; GEF 2011). Also, sustainability issues that were considered to be especially relevant to Africa, as listed by e.g. Amigun et al. (2011), were taken into account. These were: food versus fuel trade-offs, land use and tenure security, climate change and environment, impact on poverty alleviation and gender issues. Furthermore, for the analysis we made use of Gasparatos et al. (2011), who analysed drivers, impacts and trade-offs of biofuels production and use. In addition, they examined the following aspects: the impact of biofuels production on ecosystem services and biodiversity (provisioning, regulating and cultural services and biodiversity) as well as on human wellbeing (rural development, energy security and access to energy resources, food security, health, land tenure and displacement, and gender issues). From these various sources, we created an amalgamated comprehensive list of commonly used sustainability aspects on three areas of concern; economic, environmental and social, that were also frequently covered by the studies (GBEP 2009; RSB 2010; van Dam et al. 2010b; Amigun et al. 2011; Gasparatos et al. 2011; GEF 2011):

- Economic feasibility
- LCA and energy analysis
- Biodiversity
- Food security
- Local prosperity (or rural and social development)
- Labour/working conditions (or human/labour rights)
- Gender

Whenever possible, two business models that were expected to yield very different results were distinguished throughout the analysis: the smallholder model (sometimes referred to as outgrower model) and the plantation model. Smallholders are small-scale farmers who produce either independently or for a processor in a contract farming model, whereas a plantation is a large piece of land, worked by employees who are paid to harvest the seeds. There are other options or combinations possible, but at this moment these two models are observed most often.

For each of the eight aspects, the facts from the studies, methodological aspects, an explanation of the differences and an assessment of the quality of the study and the knowledge gaps are included. The studies are scored as positive, neutral or negative, depending on the main conclusion of the study. Some studies contain both a negative conclusion (for example large-scale plantations are not feasible) and a neutral one (for example smallholder jatropha cultivation is only marginally profitable or under certain conditions); such studies are listed both as negative and as neutral. Summary tables per aspect that list these scores and include the country of study, source of data and main conclusions of the studies are provided in the Appendix.

5.4 Studies used in this assessment

A total of 200 studies that cover the aspects mentioned above were identified, of which 147 were selected for further investigation[18]. One of the key selection criteria was that

[18] See references of the main article as well as of the appendix. Full details of the studies are furthermore available upon request.

studies should relate to projects that are being or were actually executed; furthermore, studies based on primary data were taken into account as much as possible.

5.4.1 Geographical coverage of the studies

A large number of studies on jatropha are available. Many are peer-reviewed articles published in scientific journals, but there is also more 'grey' literature, including field reports and reports from NGOs. In this chapter, a comprehensive and state-of-the-art overview has been compiled that focuses predominantly on literature from the period 2007-2012, in order to avoid the presentation of outdated information. Some earlier studies have been taken into account as well since they are frequently cited and widely used. Only literature in English has been considered; as a result, studies in French, Spanish or other languages have not been taken into account, with the exception of one study in Dutch (Croezen 2008) and one in Spanish (Veen and Carrilo 2009). The regions on which the literature was based were Sub-Saharan Africa (SSA), Latin America (LA) and Asia (A). Figure 5-2 presents an overview of the 26 countries represented in this analysis.

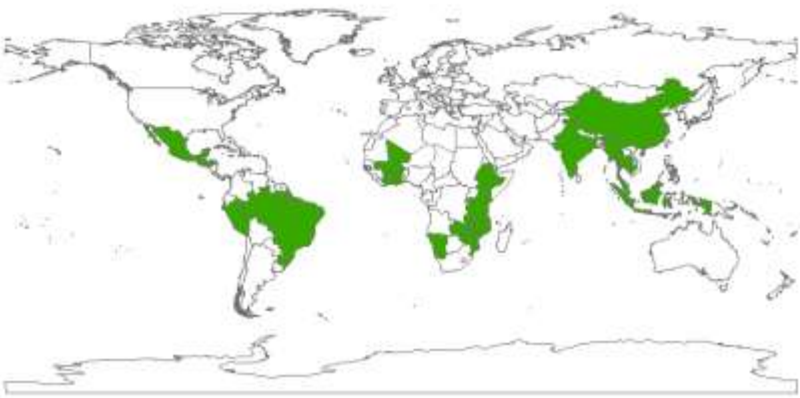


Figure 5-2: Geographical coverage of jatropha literature taken into account in this study.

A large number of studies focused on SSA (71) and Asia (37). Of the 113 studies that were country-specific, and the 71 that focused on SSA; most were based on data from Tanzania (31), Mozambique (14), Mali (5) and Kenya (5). In Asia the largest number of studies focused on India (16), while for Latin America (8 studies in total) this was Honduras (2). The small number for LA is partly due to language limitations and partly because LA only has 2% of the total amount of jatropha (ha) planted (GEXSI 2008). The remaining studies either focused on other countries or did not have a specific country focus.

5.4.2 Types of study

The studies included a large number of scientific journal articles (66), research institute reports such as FAO and ICRAF (27), NGO reports (21) and reports from industry including consultants (7). There were also 6 governmental reports, 17 Master thesis and 3 PhD thesis.

5.4.3 Quality and data source

Around 46 studies were based on field data or interviews with stakeholders in the country of study. However, for some studies it was difficult to identify the original sources of data. Around 47 studies were exclusively based on secondary sources (50 studies not indicated; see Table 5-1). In table A-4 in the Appendix, details on the number of interviews per study is provided (if available).

Table 5-1: Studies based on fieldwork or secondary data and number of peer-reviewed articles (not excluding each other).

Area of concern	Aspects	Studies based on primary data	Studies based on secondary data	Peer-reviewed articles	Total number of studies identified
Economic	Economic feasibility	15	17	14	37
Environmental	GHG/LCA	9	16	18	37
	Land use carbon stock	5	8	6	14
	Energy balance	1	0	2	2
	Biodiversity	2	1	3	9
Social	(local) food security	13	6	11	28
	Local prosperity (rural and social development)	19	8	14	40
	Labour/working conditions (human/labour rights)	9	1	2	11
	Land ownership/land rights	8	3	5	21
	Gender	6	1	3	11

In total, 58 reports were found to include one or more social aspects, 37 included economic aspects and 50 reports included environmental aspects. Furthermore, there were 45 studies that specifically focused on smallholder systems and only 21 focused on large-scale plantations. There were more studies on social aspects than on economic or environmental aspects. Within the area of social issues, some aspects were included in only a few reports, such as energy balance, biodiversity and gender issues. In the studies based on primary data, only the aspects economic feasibility, local prosperity and food security were relatively well-covered.

5.5 Analysis of the studies

In Section 5.5.1 the results of the analysis on economic aspects are presented, Section 5.5.2 is based on the environmental impacts analysis while Section 5.5.3 analyses social issues. Each section describes the following four aspects: facts from the studies, methodological aspects, an explanation of the differences and an assessment of the quality of the study.

5.5.1 Economic aspects

A total of 37 studies took economic aspects into account. Table 5A-5 in the Appendix summarises the results of the studies with respect to the current feasibility of jatropha projects (cultivation and/or processing).

In total, 10 studies were positive about the economic viability of jatropha, and 11 were negative. The majority (21) were partly neutral and indicated only marginal profitability or concluded that projects need to achieve certain yields to be viable. So in general the financial feasibility (Net Present Value: NPV) of jatropha projects is not deemed to be high. The studies indicated the following reasons for this low profitability: low yields, low price of fossil fuel, low price of by-products (although there is the potential of use as animal feed if it is feasible to detoxify the seedcake) and the high amount of labour required for harvesting. Overall, the uncertainties are considerable and therefore the results of jatropha projects vary widely. Of the studies, 25 wholly or partly focused on smallholders whereas 17 focused on plantations.

Subsidies may be provided to increase profitability for farmers in the cultivation stage. This happens in, for example, India and in Mexico (Altenburg et al. 2009; Axelsson and Franzén 2010; Skutsch et al. 2011). In India, subsidies for smallholder farmers are provided at 90% subsidy on irrigation systems and 40-100% for land preparation. Funding is provided by various sources including the government (Axelsson and Franzén 2010). In Mexico, the subsidy provided does not cover the real cost of establishment and maintenance. The number of farmers willing to participate is higher if subsidies are available. However, this affects the overall profitability of jatropha; besides, in Mexico it was observed that the subsidy was the farmers’ primary motivation to grow jatropha (Skutsch et al. 2011).

Cost Benefit Analysis results

Only 9 studies used Cost Benefit Analysis (CBA) methodology or aspects of it; 7 of these were published after 2008. The best-quality CBA research was conducted in Kenya and Tanzania. Only 5 studies included Net Present Value (NPV) calculations, and the values found varied greatly. For example, Wiskerke et al. (2010) calculated an NPV for different systems of -10,000 to 9,500 \$ ha^{-1} in Tanzania, Wang et al. (2011) calculated around -2000 \$ ha^{-1} in China, while Basili and Fontini (2009) found 56,000-2M \$ ha^{-1} (calculated with different discount values and cost options). The assumptions in these studies vary to such an extent that it is not possible to make a direct comparison of the results. Moreover, there was great variation in the calculated internal rate of return (IRR) values. For example, Loos (2008) found 16-65%, GTZ (2009b) found 14-24% in Kenya and Feto et al. (2011) found 12-16% in Ethiopia. Again, the scope of the studies varied greatly, from smallholder farming to the IRR for processing. The cost price of jatropha oil mentioned in the studies was for example 0.35-0.42 \$ l^{-1} (excl. processing costs) in Tomomatsu and Swallow (2007), 19.6 $\$_{2007}$ GJ^{-1} or 0.75 $\$_{2007}$ l^{-1} in Wiskerke et al. (2010) and 0.5-0.6 $\$_{2006}$ l^{-1} in Indonesia, calculated by Silitonga et al. (2011). In Honduras, jatropha oil was actually produced and costs were calculated as 0.77 € l^{-1} for SVO and 1.13 € l^{-1} for jatropha biodiesel, while in Mozambique jatropha SVO was 0.83 € l^{-1} (de Jongh and Nielsen 2011). Important variables that determine the CBA were purchase or lease price of land, cost of inputs (mainly fertiliser), workers' wages (and thus specific for the country of production), and the amount of labour required for cultivation. Wang (2011) and others indicated that the majority of costs occur in the feedstock production stage.

The available studies about the expected economic viability of jatropha-based activities concentrated heavily on Eastern and Southern Africa and India: 10 focus on Tanzania, 5 on Kenya, 3 on Mozambique and 6 on India.

Methodological aspects

There are 19 studies that were partly or fully based on self-collected primary data A total of 10 studies applied a CBA that included NPV or IRR calculations; 6 of these wholly or partly focused on plantations and 7 on smallholders.

Two major problems were found to have a major impact on the results: (i) estimates of seed yields have often been unrealistically optimistic in the light of the emerging body of evidence about jatropha's agronomic performance; and (ii) land and labour resources have often not been represented at their full opportunity costs. Together, these problems have given rise to overestimations of expected profitability. They are discussed in the paragraphs below. Methodological issues were also noted, such as different time frames and different discount factors, which makes it hard to compare the results of the studies. The discount factor also influences the results of the CBA (Basili and Fontini

2009). For example, Wang et al. (2011) used a discount rate of 8% (and a 30-year time horizon). At a discount rate of 6.8% both jatropha SVO and biodiesel yield the same NPV; biodiesel has a higher NPV than SVO at discount rates above 6.8%. There is also a significant variation in the time horizon used; a representative period would be 20 years since jatropha only starts yielding after several years. Many studies mention potential yield improvements which would make the economic viability of jatropha more positive. Furthermore, the prices paid for seeds greatly influence the profitability for smallholders.

Yield

Studies used yield estimates derived from different countries and different stages of maturity. For example, Moraa et al. (2009) used yields of jatropha plants that had been planted in 2006 and had therefore not reached maturity, while Tomomatsu and Swallow (2007) mainly used yield estimates from India, which seem very high. The study by GTZ (2009b) extrapolated actual yield patterns from 3-year plants to maturity, which is reached in year 8; this extrapolation was based on scientific literature, mainly from India. High and low yield scenarios were calculated in order to take uncertainties into account; in addition, a distinction was made between monoculture, intercropping and fence plantings. The estimated yields used by the various studies covering economic aspects range from around 3-7000 kg/ha/yr (see Table 5-2). However, if only observed yields are taken into account, the yield ranges from 0.4-2000 kg seeds/ha (Van Eijck et al. 2010). The sensitivity analysis performed by Wang et al. (2011) revealed that even a yield of almost 4 tons/ha/yr still leads to an unfeasible result for a plantation with a breakeven price of 0.70 €/l biodiesel while this price is 0.93 €/l at a yield of 1.5 ton/ha/yr[19]. If CO_2 credits are included (at a price of 9.8 €/ton CER (Certified Emission Reduction), seed yield should be 2.3 ton/ha/yr for financial breakeven (Wang et al. 2011). In the study by Van Eijck et al. (2013), doubling the yield almost triples the NPV: a yield rising from 1 ton/ha/yr to 2 ton/ha/yr leads to an increase in NPV from 15 to 41 M$/ha. Similarly, Loos (2008) also indicated that yields should increase to above 2 ton/ha/yr, while Ariza-Montobbio and Lele (2010) indicated that yield should increase to above 2.5 ton/ha/yr to make cultivation on a plantation viable. Thus, a yield increase to above 2-2.5 ton/ha/yr seems the minimum yield for plantation systems. The maximum yield for jatropha is 7.8 ton/ha/yr, so 2-2.5 ton/ha/yr seems achievable (Jongschaap et al. 2007).

Table 5-2: Specific dry seed yield data from the studies

Country	Setting	Yield Kg/ha/yr	Source
Tanzania	in semi-arid conditions	3200-4800	(Kempf 2007)
Kenya	rainfed irrigated	3700[a] 7900[b]	(Tomomatsu and Swallow 2007)
India	from 5th year onwards	1800	(Francis et al. 2005)

[19] Exchange rate €/Yuan: 9.64 (February 2010, retrieved from www.oanda.com)

Tanzania	low inputs to high inputs	1000-3000	(Struijs 2008)
Tanzania	in year 3 estimates, smallholders semi-arid	259 1500-5200	(Loos 2008)
Mozambique	highest estimate	300/4000	(Econergy International Corporation 2008)
Tanzania	from year 3 onwards in fertile area using occasional flood irrigation and virtually no fertiliser	1700	(Messemaker 2008)
Kenya	Shimba hills, Monsoon climate, rain twice per year, 400-1200 mm, sandy soil	250[c]	(Moraa et al. 2009)
Kenya	Semi-arid region, smallholders, yield estimate for mature trees (after 9 years	420-1370[d] 150-500 270-450	(GTZ 2009b) yield for monoculture, intercrop field and fence respectively.
Tanzania	Northern Tanzania, smallholders, rain twice a year, <1000-2000mm, neogene soils, yield from year 5 onwards	2000[e]	(Wahl et al. 2009)
Tanzania	Based on literature from India	7000	(Mulugetta 2009)
India	Mature rainfed to mature irrigated	3450-5200	(Estrin 2009)
Tanzania	Northern Tanania, smallholders, semi-arid, from year 9 onwards	2 kg/shrub	(Wiskerke et al. 2010)
India	(Tamil Nadu) rainfed or irrigated	450-750	(Ariza-Montobbio and Lele 2010)
India	For mature plantations	1000-1250	Various studies cited by (Brittaine and Lutaladio 2010)
India (south)	Tamil Nadu and Andhra Pradesh, smallholders, rainfall average 940-960 mm/year, various inputs used, manure and irrigation	3-2500[h]	(Axelsson and Franzén 2010)
No specific focus	Worst-medium-best case estimates (from literature)	3000-5000-7000	(Hawkings and Chen 2011)
China	Yunnan province, plantation on marginal soil, fertilisers applied. Maximum yield from the 5th year onward	1485[f]	(Wang et al. 2011)
Indonesia	In poor soils 1 kg/tree, other soils 2-4 kg/tree	1590 kg/ha (oil)[g]	(Silitonga et al. 2011)
Mali Honduras	Smallholder farmers using low inputs, Mali average rainfall in the area 800m and Honduras 1200 mm/yr small amounts of fertiliser or manure used, yield after 2 or 3 year	500 450[i]	(de Jongh and Nielsen 2011)

[1]: small scale or large scale, plantation or smallholders

[a]: original data in kg/acre, 1500 kg, conversion factor 2.47.

[b]: original data in kg/acre, 3200 kg/acre, conversion factor 2.47.

[c]: original data 0,5 kg/tree and 100 kg/acre, conversion factor 2.47.

[d]: data obtained from 143 surveyed farms in Kenya of mostly 3 yrs old, original data in kg/acre.

[e]: 875 kg/ha was observed but only on one field, therefore the study used 2000 kg/ha as an estimate.

[f]: yields are based on field survey and literature.

[g]: value taken from literature, citing Singh et al 2007.

[h]: based on survey in 2005 and 2010 with in total 113 respondents, in total 21 respondents harvested jatropha.

[i]: From good performing fields, although there are high yield variations between different fields.

In their assessment of the economic viability, studies generally emphasise the cultivation stage. Sometimes, but not always, this included a comparative viability assessment of different crops. A handful of studies also included the oil and biodiesel processing stages and the market situation with respect to jatropha by-products, and tried to assess their competitive situation versus competing products. However, most studies did not include a value for seedcake in the CBA.

Cultivation costs

A number of studies differentiated between more than the two business models identified by this study; besides considering plantations and smallholders, they also looked at fence cultivation. The study by GTZ (2009b) was one of the very few studies that provided primary cost data. This study indicated that the establishment costs for fences are low and that fence cultivation is beneficial for farmers, as long as there is a market for the seeds. The GTZ study calculated 824 $/ha establishment costs for mono plantations and 103 $/ha for fences. If it is assumed these are the only costs in the first 3 years of a jatropha project, these costs amount to approximately 325 $/ha (exchange rate November 2010) for a mono plantation scenario. Of this, 30% are labour costs, excluding opportunity costs of unpaid labour (GTZ 2009b). Some studies indicated that a subsidy is provided for farmers to cover their cultivation costs (e.g. (Axelsson and Franzén 2010).

Prices paid for seeds

There are only limited differences between the prices paid to farmers for the seeds; they vary from 0.05-0.18 $ kg^{-1}, with short-term peak prices. In Mexico, 0.12-0.18 $ kg^{-1} is paid for seeds to keep jatropha SVO competitive with fossil diesel, although short term peak prices up to 0.54 $ have been reported (Skutsch et al. 2011). In Honduras the price is around 0.10 $ kg^{-1}, while in Mali the price is 0.05 $ kg^{-1} (de Jongh and Nielsen 2011). In Tanzania seed prices are also around 0.10 $ kg^{-1} (Van Eijck et al. 2012). Roughly 4 kg of jatropha seeds is required for 1 litre of oil. Therefore, the price of seeds is often established in such a way that jatropha SVO is competitive with fossil diesel.

Quality judgement and knowledge gaps

The evidence suggests that the financial feasibility of jatropha cultivation under current conditions and with the current state of knowledge and experience is quite poor. On fertile lands and with the use of irrigation and fertiliser, cultivation results in reasonable or even good dry seed yields of 2-4 ton/ha/yr. However, under these conditions the same resources can produce far more profitable food crops. On wastelands with zero opportunity costs, yields would be far too low to be of economic interest (<1 ton/ha/yr).

For settings that include marginal and grazing lands, the opportunity costs of land and labour (and water supply) cannot be assumed to be zero, while yields will be modest unless substantial supplementary inputs, such as fertiliser and water, are provided. The unviability of this type of cultivation has been estimated quite convincingly for China by Wang et al (2011). The findings for oil processing are not much better than for cultivation. At present, jatropha biodiesel cannot compete with fossil fuel on domestic markets. For jatropha to become a viable biofuel in those markets, its value chain needs to be more profitable. This may be achieved by finding higher-value uses for by-products (especially seedcake), further increasing oil-processing efficiency, developing seed varieties with higher and more reliable seed yields under semi-arid conditions, and optimising cultivation practices. However, considering the perennial characteristic of the crop, it is unlikely that these challenges will be resolved within a few years.

Currently, one of the most feasible scenarios that emerges from the studies is resource-extensive jatropha hedge cultivation. This practice has very low opportunity costs and can be undertaken on fertile lands with good water access. Therefore, some studies therefore state that jatropha cultivation other than as hedge plantings or small scale projects should not be recommended for the time being (GTZ 2009b; Broadhurst 2011). Furthermore, some projects focus on local self-sufficiency and link seed production closely to local processing and oil use. Such projects appear to have better potential for achieving financial viability than larger projects focused on the use of the oil in other places. This can be explained by the ability to return the seedcake to farmers as fertiliser and the use of jatropha SVO for local applications, instead of the production of more expensive biodiesel. Seed and oil production for export to the EU has been unprofitable due to stiff competition from subsidised bioethanol from the US. This may change when niche markets with high sustainability requirements develop, such as biokerosene feedstock for airlines, and when official biofuel sustainability norms come into force in the coming years.

Many studies lack original and measured field data, such as yields that are reliably measured and accurate cost data of the projects. These data are still scarce as most jatropha projects are in a too early stage to measure yields from mature plants, and no large quantities of jatropha oil have yet been produced in these projects. However, for large investments, more detailed information is necessary to design a proper business case and to prevent project failure.

5.5.2 Environmental aspects

The environmental aspects that have been included are Life Cycle Analysis (LCA) and energy balance, and biodiversity.

5.5.2.1 LCA and energy analysis

A total of 45 studies have taken environmental issues into account, of which 36 include LCA and 18 include carbon stock and energy balance calculations. As shown in Table 5A-6 in the Appendix, the scope and goal of different ecological assessments of jatropha bioenergy can differ widely.

Studies comparing jatropha biofuels to fossil fuels conclude that jatropha biodiesel is preferable over fossil diesel, based on the analysis of greenhouse gas (GHG) balances, excluding Land Use Change (LUC); however, this conclusion is sometimes based on estimated data and assumptions which are highly uncertain and/or whose validity is doubtful. These assumptions will be discussed in the next paragraph. Only if land with high carbon stock is converted to jatropha plantations, can the LCA be negative compared to fossil fuel. This is demonstrated in the sensitivity analysis of (Paz and Vissers 2011), for example. The IPCC has also included jatropha in their overview of renewable energy sources and the lifecycle GHG emissions of jatropha, about 25 to70 CO_2 eq/MJ fuel, falls within the range for palm oil of about 18 to 75 CO_2 eq/MJ fuel (IPCC 2012, fig 9.9).

Assessments comparing different biofuels sometimes reached conflicting conclusions, due to variations in local circumstances, differences in processes or differences in assumptions, especially with respect to by-product allocation. For example, some studies indicated that jatropha oil or biodiesel has a lower GHG emission than palm oil (Dehue and Hettinga 2008; Ndong et al. 2009; Ou et al. 2009), whereas other authors, such as Lam et al. (2009) and Veen and Carillio (2009), concluded that palm oil leads to higher GHG savings than jatropha oil. In the IPCC study, which compared several biofuels, jatropha oil has emissions similar to those of palm oil, while rapeseed (EU) and soybean (US) have lower emissions, this is without considering LUC (IPCC 2012). However, including LUC, jatropha is assessed as more having more favourable emissions than palm oil, with a range of -100 to 100 g CO_2-eq/MJ for jatropha and approximately -20 to 350 g CO_2-eq/MJ for palm oil. This result stems from the possibility of growing jatropha on marginal soils; palm cannot be grown on marginal soils.

An assessment of biogas production from jatropha concludes that it may be more efficient to use jatropha seeds for anaerobic digestion, rather than first obtaining oil and then producing biogas from the seedcake (Gunaseelan 2009).

Centralised versus decentralised processing of the seeds can also make a difference: Reinhardt et al. (2007) concluded that centralised jatropha processing facilities in India deliver better GHG results and need less fossil resources than decentralised ones. In centralised facilities, the longer transport distance is compensated by higher oil extraction and lower energy consumption during processing.

The studies use different functional units and are therefore difficult to compare. The 14 studies that include a percentage of emission reduction compared to fossil fuel are shown in Figure 5-3. The black triangle indicates the average of the values mentioned in the studies, and the green bar shows the range (if applicable). All averages indicate a reduction (from 14-180%) compared to fossil fuel, the total range of the studies is -85% to 300%; the negative values are due to land use changes.

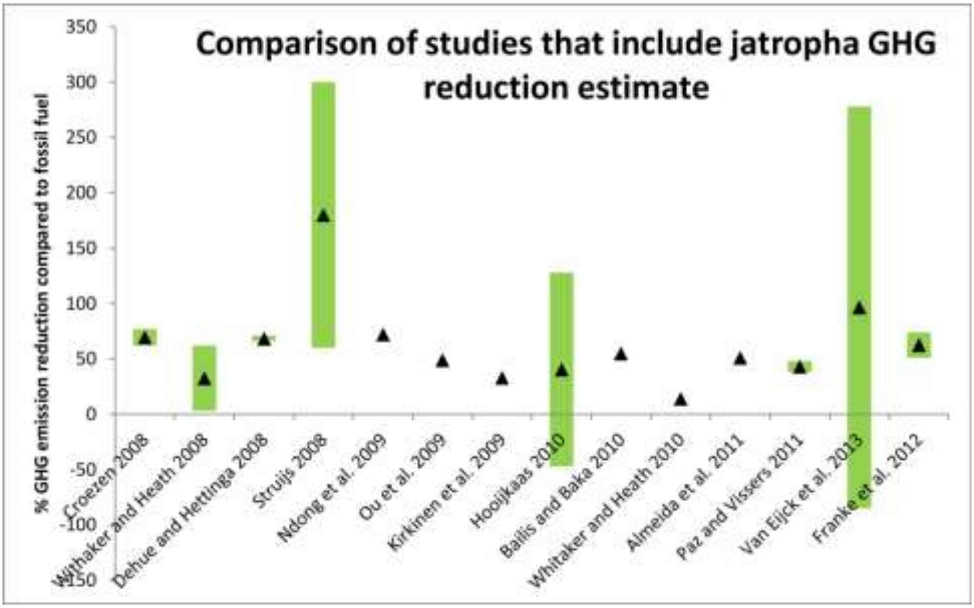


Figure 5-3: Emission reduction % indicated by the studies, average (black triangle) and range (green bar) per study

Note: the range in Paz and Vissers (2011) is 39-48%; however, in their sensitivity analysis their range is 15-74% emission reduction.

Methodological aspects

In addition to the factors mentioned above, there are important differences in the conclusions of the various studies which also derive from differences in their assumptions. These differences include yield, the way in which by-products are utilised, and the end-use (e.g. fuel or electricity). Furthermore, differences are due to methodological choices in different models, for instance in by-product allocation[20].

As regards the cultivation stage of jatropha, it is striking that the differences in assumed seed yield are very high (Table5-3). They range from 0.4-12t/ha/y.

Table5-3: Seed yields used in the studies

Location	seed yield (t/ha/y)	References
Malaysia min	0.4	(Lam et al. 2009)
Small holders Tanzania	1	(Struijs 2008) p38
Critical for GHG reduction	1.25	(Whitaker and Heath 2010) p xi
Poor soils today	1.418	(Reinhardt et al. 2007) p11
Infertile soil	2.382	Stuttgart et al. In (Lam et al. 2009)
Poor soil optimised	2.382	(Reinhardt et al. 2007) p11
Average Indian village	2.5	(Gmünder et al. 2010) p350
Seed yield India low	3	(Dehue and Hettinga 2008) p3 + p27
Raipur India	3.75	(Whitaker and Heath 2010) p6
Ivory Coast	4	(Ndong et al. 2009) p201
India	4.05	(Gunaseelan 2009)
Poor soil best	4.436	(Reinhardt et al. 2007) p11
India	4.5	Achten et al, in (Whitaker and Heath 2010) p4
India base case	4.5	(Dehue and Hettinga 2008) p3 + p27
India	5	(Arvidsson et al. 2010) p8
Good conditions Malaysia	5	(Lam et al. 2009)
Malaysia	5	(Lam et al. 2009)
China	5	(Ou et al. 2009)
Peru average	6	(Veen and Carrilo 2009) p38
India high	6.3	(Dehue and Hettinga 2008) p3 + p27
Perennial plantation Thailand	8.75	(Prueksakorn et al. 2010) p3
Malaysia max	12	(Lam et al. 2009)
Mozambique, Manica	3	(Paz and Vissers 2011)
India Tamil Nadu	11	(Pandey et al. 2011)

The energy contained in the different by-products is high; therefore, the use of by-products has a great impact on the energy and GHG balances.

Regarding the energy use and GHG emissions of the different process steps, it has become clear that transesterification and fertiliser application are the main contributors. Gunaseelan (2009) reports that 67% of the energy required is used in transesterification and 18% is used for fertilisers; in addition, transesterification is responsible for 52% of the GHG emissions and fertiliser use for 35%. However, emissions due to land use change have not been taken into account, even though they are an important factor. According to (Sampattagul et al. 2007), the largest contributor to GHG emissions is the

20 Dehue and Hettinga (2009) conclude that RTFO has to change its co-product methodology allocation by energy content, in order to be consistent with the EC proposal (Dehue and Hettinga, 2008).

cultivation stage (45%), followed by the biodiesel utilisation stage (30%) and biodiesel production (28%); this study did not include any LUC effects. Ndong et al. (2009) also concluded that the GHG emissions in cultivation constitute 52% of total emissions (mainly due to fertiliser), transesterification accounts for 17% of GHG emissions, whereas final combustion accounts for 16% (no LUC effects included). The study also calculated the energy consumption of all steps: transesterification 61%, transport (of all products) 15% and cultivation 12%. Thus, most authors agree that the cultivation stage is the largest contributor to GHG emissions, and transesterification accounts for the largest energy consumption in the process chain. In addition, one study added that irrigation is a major contributor to environmental impacts, as well as the end-use phase and land use changes (Achten et al. 2008).

Some authors include a **sensitivity analysis.** The following conclusions can be drawn from the review:

- According to Dehue and Hettinga (2008), GHG performance is sensitive to oil and seed yield, but not as sensitive as expected, due to the relatively low GHG emissions in the cultivation, transport and extraction stages, compared to the emissions in oil transport and in the transesterification stage. Transesterification is the largest contributor (43%), followed by oil transport (34%) and land use change (15%). It is assumed that grassland is converted to jatropha plantations. Cultivation is 0% as it is assumed that no inputs are used.

- (Whitaker and Heath 2008) performed a sensitivity analysis on selected parameters and found that tree planting density, seed yield and seed oil content have a substantial influence on LCA results. In addition, the environmental impact of individual plantations is site-specific and depends on seed yield (Whitaker and Heath 2010).

- Prueksakorn and Gheewala (2008) concluded from their sensitivity analysis that the biodiesel yield, co-product yields, farm energy inputs, energy consumption in the oil extraction process and energy consumption in the biodiesel consumption process are the largest contributors to GHG emissions; however, they did not include LUC in their analysis.

- Arvidsson et al. (2010) found that variations in crop yield and in nitrous oxide emissions from microbial activities in soil may cause significant changes in the results.

- The LCA is sensitive to seed yields (increase of 1 tonne/ha results in a 10% reduction of GHG). Besides, transport by truck instead of freight train has an impact similar to yield (564 km by train leads to a reduction by 8-14%). The energy consumption of the labour force has been included by using a worker's average daily ratio (2300 kcal/day); this reduces energy yield by 27%. Local use of jatropha biofuel instead of transporting the biofuel has important effects: the energy yield ratio rises from 4.7 to 26.4 and GHG savings increase from 72% to 85% (Ndong et al. 2009).

- The sensitivity analysis performed by Paz and Vissers (2011) showed that seed yield is by far the most important defining parameter (using a yield of 1.5 instead of 3 ton/ha/yr results in only 15% savings instead of 48%). Oil yield and the input of nitrogen fertiliser also have a significant impact. The influence of phosphate fertiliser is only minimal.

- The average sequestration rate by jatropha trees used by Ndong et al. (2009) citing (Reinhardt et al. 2007) is 900 kg C $ha^{-1}yr^{-1}$.

- Arvidsson et al. (2010 p8) concluded that a drop in seed yield from 5 tonnes/ha to 0.5 tonnes/ha would increase Global Warming Potential (GWP) by 770% whereas an increase in seed yield from 5 to 12 tonnes/ha would decrease GWP by 43%.

- The main factors that Bailis and Baka (2010) indicated in their sensitivity analysis are land use change and yield.

Quality judgement and knowledge gaps

The analysis revealed six critical aspects for the assessment of environmental impact of jatropha biofuels:

Land use change: This assessment confirms the patterns signalled in an earlier jatropha review by Achten et al. (2008), i.e. cultivation on degraded soils and waste lands gives the greatest reduction in GHG emission. However, the GHG balance can turn unfavourable when cultivation leads to a reduction in the carbon stock by the removal of existing vegetation, for example when forest and woodland areas are used (Reinhardt et al. 2007; Dehue and Hettinga 2008; Veen and Carrilo 2009; Bailis and Baka 2010; Romijn 2010; Van Eijck et al. 2013). Arvidsson et al. (2010) also concluded that the significant contribution of global warming potential originates from soil during cultivation.

Usage and allocation of by-products: The by-products of the production of biodiesel from jatropha (seedcake, biogas, glycerin) contain a large amount of energy; together, these products hold slightly more than half of the energy contained in biodiesel (Lam et al. 2009). Prueksakorn et al. (2010) reported that the energy content in the seedcake produced is almost double the energy contained in the biodiesel produced. Therefore, the use of by-products is crucial for the outcome of the LCA. The use for energy production allows a significantly higher GHG reduction than the use for fodder or fertiliser, due to higher fossil energy savings. This was shown in the study by Reinhardt et al. (2007), who calculated LCAs of different value chains. If none of the by-products is used for energy, the energy balance is slightly positive: 0.89 MJ energy input per MJ Jatropha biodiesel output; however, if all by-products are used efficiently, the energy input per MJ Jatropha biodiesel output can be reduced to 0.16 MJ per MJ JME output (Achten et al. 2008).

Fertiliser usage: Applying N-fertiliser results in direct emissions and indirect soil emissions and leads to a significant worsening of GHG performance (Struijs 2008). P-fertiliser and lime addition have only a limited effect on GHG performance (Dehue and Hettinga 2008). Ndong et al. (2009) also concluded that it is necessary to limit fertiliser use in order to reduce energy use and GHG emissions. Ou et al. (2009) found that fertiliser input is a major GHG factor. Nitrogen emissions also have negative results in other environmental impact categories, such as eutrophication. Of course, there is a trade-off in applying less N-fertiliser on degraded soils and yield. Thus, fertilisation is necessary to maintain long-term seed yields; since the plant is not a nitrogen-fixing species, harvesting the seeds leads to regular nutrient removal (Openshaw 2000; Achten et al. 2007). According to Struijs (2008), nutrients are the limiting factor in degraded soils in Northern Tanzania where the jatropha is cultivated; in such situations, eutrophication may be welcome. Moreover, as mentioned by Basili and Fontini (2009), considering that fertilisation is responsible for 30% of the GHG emissions, the GHG balance can be improved by using natural fertiliser such as seedcake or organic manure, rather than mineral fertiliser, even though Reinhardt et al. (2007) concluded that the energetic value of seedcake is more valuable. Furthermore, if seedcake is used as fertiliser, the GHG reduction performance of the jatropha chain will be significantly reduced because the seedcake is no longer an energy by-product to which part of the emissions can be allocated.

Nitrogen contributions to GHG: These are often only partly incorporated; however, Arvidsson et al. (2010) concluded that more than half of global warming potential is caused by nitrous oxide emissions from soil. These emissions originate from both fertiliser and microbiological activity in the soil. The impact of nitrous oxide emissions may be underestimated.

Energy use in the transesterification phase: As transesterification is responsible for 23% of GHG emissions, the GHG balance can be improved by consuming the Straight Vegetable Oil (SVO) (Basili and Fontini 2009). Ndong et al. (2009) suggested that to reduce both energy requirements and GHG emissions, a reduction is necessary in the energy and chemicals used in the transesterification process. Alternatively, using jatropha oil in the form of SVO would reduce GHG emissions by 45% and energy use by 82% (Ndong et al. 2009).

Transport: Long-distance intercontinental transport of seeds or oil has a major impact on the LCA. Ndong et al. (2009) reported that oil transport from Ivory Coast to France claims 75% of the energy use of transport (around 12% of the total energy use in the jatropha diesel production life cycle). Local production of biodiesel would reduce energy use by 10% and reduce GHG emissions by 2% (Ndong et al. 2009). In some countries, due to bad infrastructure and inefficient combustion in heavy duty trucks, rail transport may be preferable for inland transport. In India, transport by train (0.19MJ/t*km) instead of by truck (1.94MJ/t*km) would improve overall GHG performance by 3% pt (111 to 118 kg CO2 eq/t biodiesel; in (Dehue and Hettinga 2008). Furthermore, a mobile expeller, if not changing oil yield and energy use, reduces GHG intensity by 75% for the extraction phase by reducing transport needs (Dehue and Hettinga 2008). Reinhardt et al. (2007) also indicated that transport has a large influence; the exact influence is determined by transport distances and modes, which in turn are influenced by the business model (e.g. central or decentralised processing), the factory capacity, land use intensity and yield levels.

Based on the literature reviewed in this section, it can be concluded that jatropha biofuels may contribute to significant GHG reductions compared to fossil diesel, especially when limited inputs are used and land converted to jatropha does not have a high carbon stock (e.g. virgin Miombo Woodland or pristine forest). The main critical issues (which may also make the LCA negative) are: land use change and the initial carbon debt, the input used in the cultivation stage (especially fertilisers and pesticides), the use of by-products, energy use in the transesterification stage, and transportation mode and distance.

The issues discussed above demonstrate that an LCA should be performed for specific sites, for the specific jatropha products that will be used, and for specific business models. Except for location-specific data such as data on soil carbon and previous land cover, most data necessary to perform an LCA for jatropha is available; one of the most comprehensive LCA tools which includes relevant data is the GHG calculator developed by IFEU (Franke et al. 2012).

It is necessary to gain more insight into the specific environmental impacts acidification, eutrophication and nitrous oxide, as well as into how these impacts can be minimised. Moreover, the most efficient use of by-products is not straightforward, since they can be used as energy sources or as fertilisers. Some studies, such as Gunaseelan (2009), included the production of biogas from various jatropha products (wood, seedcake), whereas others, such as Gmünder et al. (2010), took the production of electricity into account. In still other studies, seedcake is used as a fertiliser and therefore no GHG emissions are allocated to the seedcake (Franke et al. 2012). There will be trade-offs between the different dimensions of using the by-products of jatropha, including GHG emissions, cost-benefit, energy-efficiency, long-term soil health and yields.

5.5.2.2 Biodiversity

Nine studies investigated the impact of jatropha projects on biodiversity. Three of these studies focused on Tanzania, whereas the other studies all focused on different countries, see Table 5A-7 in the Appendix. Only two studies found a positive impact (increase of biodiversity), six were neutral and four found a loss of biodiversity. Only two studies actually measured or observed changes in biodiversity; families interviewed in Brazil by study (Finco and Doppler 2010), found that per family 0.72 h was deforested, and in Mexico (Skutsch et al. 2011) some deforestation was observed but only limited.

The impact on biodiversity varies with the specific location of the jatropha trees. Prueksakorn and Gheewala (2008) found that there are two determining factors: previous land use and intensity of production.

Previous land use

In the projects in Mozambique visited by Schut et al. (2010b), the natural vegetation was cleared, but some indigenous trees were left. A study by Van Eijck et al. (2013) measured the above-ground biomass in the area targeted for a plantation and found forests with high C-stocks. Some reports mention that existing projects have a potentially negative influence on biodiversity due to their location. In Mozambique, the ADPP/FACT project (in Bilibiza) is located in a National Park, and two other projects are located close to high-biodiversity areas (Schut et al. 2010b), citing (FACT Foundation 2010). However, this negative influence on biodiversity may be avoided by not targeting forest areas or other biodiversity hot-spots for jatropha plantations. Fragmentation of forests has not been included in the studies.

Intensity of production

There is no record that jatropha cultivation has any impact on the biodiversity of indigenous floral species (ProForestLtd. 2008, citing de Padua et al. 1999). The intensity of production is determined by the level of inputs used. The impact on biodiversity is largely unknown and not targeted in the studies assessed. Generally, the use of biofuels increases eutrophication, acidification and nitrous oxides emission compared to fossil fuels (Reinhardt et al. 2007).

Methodological aspects

There are only three studies that have measured or observed (potential or actual) changes in biodiversity due to jatropha projects. Of these three studies, only two; Finco and Doppler (2010) and Van Eijck et al. (2013), made a quantitative impact assessment. In the study by Van Eijck et al., field measurements were made of an area targeted for conversion into a jatropha plantation. However, in the end this area was not actually converted. A third study, Skutsch et al. (2011) made observations on (limited) deforestation in Mexico by interviewing smallholders. Interestingly, all three studies indicate possible or actual negative impacts. The other studies only describe the potential risks beforehand. Both Finco and Doppler (2010) and Van Eijck et al. (2013) concluded that biodiversity was negatively affected due to deforestation. However, as Ravindranath et al. (2011) pointed out, policy measures may be implemented to prevent the conversion of forest and to stimulate biofuel production on marginal lands. However, it is questionable whether this would be attractive from a financial and social point of view. In Section 5.5.1, it was already noted that jatropha cultivation on marginal soils is financially unattractive due to very low yields. Moreover, marginal lands are commonly used by land-poor people for other purposes such as grazing and collecting forest produce (see also Section 5.5.3.4.).

Quality judgement and knowledge gaps

Only a few reports have analysed the impact on biodiversity. Most studies that mention biodiversity have analysed the effect of previous land use but not the effect of production intensity. Typically, smallholders do not have a high intensity of production; they often do not use pesticides or herbicides. However, for plantations this is usually very different. It is only possible to determine the biodiversity impact more accurately if a baseline study has been carried out in advance. In some countries companies are obliged to carry out an Environmental Impact Assessment (EIA) if they want to receive a licence to operate. An EIA could serve as a baseline study if it is objective, reliable and of high quality.

As the impact on biodiversity is very location-specific, the results of the studies that analysed the impact on biodiversity in a specific location cannot be transferred to another area. Still, these studies may be useful in the comparison of locations and in the comparison and harmonisation of the methodologies used. Conversely, it is possible to use the results of the studies on the carbon stock of jatropha plantations for other locations. Generally, mono crop-plantations planted on newly cultivated areas decrease biodiversity. However, there are measures to overcome this, such as planting in several blocks, leaving areas of original vegetation untouched, and performing a zoning or mapping exercise on a national level to identify areas that can be converted with minimal impact. Therefore, clear guidelines are required for spatial planning that minimise negative impacts.

5.5.3 Social issues

Five social issues are addressed in this assessment: food security, local prosperity and well-being, labour and working conditions, land ownership and land rights, and gender issues.

5.5.3.1 Food security

The four dimensions of food security, as defined by FAO are: food availability, access to food, stability of supply, and utilisation of food for individuals, households, communities and larger population groupings (FAO 2010b; UNFAO 2010).

In Table 5A-8 in the Appendix, 26 studies are summarised that included an analysis of food security impact. Of these studies, twelve mention a negative impact on food security, while no negative impact on food security was found by twelve other studies, including the comprehensive report of the FAO. Eight studies observed a partially positive effect. The negative impact found is all due to food replacement by jatropha, either directly, by crop substitution on land, or indirectly, by a reduction in the time spent on tending food plots. Most studies focused on smallholders.

The most comprehensive study is a study by the FAO on biofuel crop production and food security in Tanzania. The research team found no significant negative impact and concluded that even a slight increase of current yields will offset any effect on food security (FAO 2010a). However, two other studies in this assessment, also based on actual observations (in India and Brazil:(Ariza-Montobbio 2009; Finco and Doppler 2010) note that food security can be negatively affected if the cultivation of food crops is replaced by jatropha and the increased household income does not compensate this. This is highly relevant due to the low financial benefits of jatropha. Thus, food security may be affected, but there are measures to offset this effect, such as favourable working hours on plantations, sufficient wages to purchase food, and ensuring that jatropha should not replace food crops at smallholder plots, e.g. by promoting fence cultivation only. The issue of food security is also closely related to poverty reduction and rural development and (Ewing and Msangi 2009; Van Eijck et al. 2013). Portale (2012) analysed the food security perception of jatropha contract farmers and non-jatropha farmers. The jatropha contract famers reported lower food shortages and considered their food security level higher than before cultivating jatropha, as a result of their additional income.

The issue of food security is more urgent if jatropha plantations are situated in areas with a high prevalence of food insecurity. For example, one plantation company in the South of Tanzania is situated in a region which produces just enough food for three to four months after harvest. During the remaining months people have to buy their food (FAO 2008a). Specific measures may be taken to minimise impact; for example, the plantation company established a school vegetable garden in a nearby village, where local children could learn about agricultural practices which would increase food production (Gordon-Maclean et al. 2008). However, among the projects visited in Mozambique by Schut et al. (2010b), only a few initiated food-security projects. Schut et al. (2010b) concluded that on the current scale this will probably not endanger food security in the short-term, but that the long-term effects are unclear. Farmers employed as labourers on plantations spent less time on their own food plots, which resulted in decreased food production (Peters 2009). Chachage and Baha (2010) also observed a decline in food production because labourers lacked the time to tend their food plots. Still, measures may be taken to overcome this situation; for example, in Mozambique the workers have favourable working hours (e.g. until 4 pm) to enable them to continue working on their household farm (Peters 2009). Other measures that can be taken by plantations are the inclusion of smallholders in their business model and a plantation system that uses intercropping (Mwamila et al. 2009).

Mshandete (2011) pointed out that even in smallholder systems the effects on food security may vary according to differences in implementation. As opposed to monocropped systems, intercropped systems provide benefits of intensification and diversification of cultivation and reduce the risks of pests and diseases. In such systems, spacing and crop choice are important (Prakash 2012).

Methodological aspects

Most studies base their conclusion on interviews, by asking whether people feel food insecure or asking about their diet and the number of meals they eat. The conclusion is often based on either anecdotal data and only sometimes on statistical analyses which include a control group e.g. Loos (2008) and Peters (2009). One study, (Portale 2012), created an index for the perception of food security, again based on the question as to whether smallholders felt that they had been running out of food in the last twelve months. Food security can be very different across local areas and even across households, and therefore the response to these questions probably provides an accurate image of specific locations. However, it is difficult to link any changes in perceived food security to biofuel projects as such changes may also be due to external reasons such as drought. Moreover, the number of respondents varies per study from 10 to more than 200. The accuracy of the analysis and conclusions of the studies may vary according to the number of sample observations in relation to the relevant population size, as well as according to the method of questioning. It is difficult to draw any meaningful conclusions about the optimal number of respondents, without an in-depth insight into the local setting.

Many studies provide more general remarks on possible effects, such as Mwamila et al. (2009), who mentioned possible food crop replacement. Other studies use food production statistics from the region to give more background information and in this way enable a better interpretation of the effects of jatropha projects e.g. Habib-Mintz (2010) and Finco and Doppler (2010).

Some studies take a wider perspective and try to take more elements into account. For example, German et al. (2011b) analysed the food security situation of jatropha smallholders in Zambia by looking at the changes in land area under food crops before and after the introduction of jatropha, changes in net food production, changes in the quality of the land allocated to food crops, and the loss of revenues and/or safety nets that non-timber forest products provide in the event of deforestation. The increase in food supply that they found was possible because smallholders cultivated new areas for jatropha in which they intercropped with food crops and some food crops were planted in new areas with better soil. In places where jatropha was planted as a monoculture crop, the amount of food produced was less due to displacement.

Ewing and Msangi (2009) examined various food security variables. As key indicators they used major dependence on local food and energy, agricultural land availability, and women's productive use of time. They concluded that countries with a high reliance on biomass for energy and a high incidence of hunger, such as Tanzania and Mozambique, should invest in energy technologies with positive spillovers into food production and in employment opportunities for the poor. Biofuel development may improve purchasing power and decrease the vulnerability to international price shocks. Especially outgrower schemes may induce technology spillovers into food production (Ewing and Msangi 2009).

Although Arndt et al. (2011) did not specifically look at jatropha projects, they used an interesting methodology to study food security in scenarios with jatropha production: a gendered dynamic computable general equilibrium (CGE) model based on Mozambique (see also Section 5.5.3.5). They concluded that the increased Gross Domestic Product (GDP) reduces poverty, but that there is a trade-off between biofuels and food availability if female labour is used intensively and as a result women are not available for food production. Modest improvements in both women's education and food crop yields can offset these impacts.

Quality judgement and knowledge gaps

To analyse the food security situation of the local population, ideally repeated measurements should be carried out that combine a sizable number of relevant factors. So far, most studies indicating whether an area is food secure or not have been unable to link this aspect to jatropha activities. If jatropha replaces food crops, the local production of food decreases; this can only be offset if the population earns enough money to purchase food, and if the market infrastructure allows such food purchases. In this assessment, several measures have been identified that can help to reduce food insecurity: favourable working hours on plantations, provision of agricultural knowledge especially for women and avoidance of the displacement of food crops by planting jatropha in areas not used for food crops, such as hedges. However, if a project was discontinued, it remained unclear whether the local population could re-access land that was formerly used for fire wood collection and other activities, but that was subsequently appropriated by the plantation. This has happened in some cases in Africa (eg. the Bioshape plantation in Tanzania and the Sun Biofuels plantation in Mozambique), and it is potentially a serious problem. Explicitly including this aspect in the land lease contracts may avoid this problem, since often national laws are unclear about this aspect due to lack of precedence. The complex linkages between biofuel production and food security require more research, but so far results have indicated that food security does not have to be at risk if projects are carefully implemented. More comprehensive long-term studies are needed that include all major dimensions of food security. These should be based on primary data collected on site at biofuel projects. They should disseminate lessons on how to minimise any negative impact on food security. In this assessment, FAO (2010a) was the only study that investigated all four food security dimensions.

5.5.3.2 Local prosperity and well-being

Local prosperity and well-being of the local population can be achieved through increased household income and increased access to, for example, education, health facilities and energy. Furthermore, greater knowledge about e.g. cultivation techniques or technical skills by local communities through training and advice can lead to increased local prosperity.

Table 5A-9 in the Appendix includes an overview of the 39 studies that deal with (aspects of) local prosperity and well-being. Nearly all studies mentioned a positive impact on poverty reduction for smallholders. Only one report indicated that the poorest households may not benefit if the owners of the jatropha trees do not allow them to pick seeds; however, this study also describes positive impacts, such as increased household income (Mitchell 2008a). There were only a few studies that mentioned a negative effect on the local economy and local employment, mainly due to the discontinuation of projects and the delayed financial gains. Five themes were frequently mentioned in the studies: impact on energy access, poverty or livelihood/local economy, employment generation, skills, and attitudes and well-being. The main findings for each theme are described below.

Energy access

Especially the use of jatropha oil by local communities has a positive effect on local prosperity and well-being because it leads to increased energy access, either through electricity generation (by using SVO or biodiesel in a generator), by using the oil in cooking stoves, or by using the by-product, seedcake, as a substitute for fuelwood or charcoal. Still, there are some socio-organisational issues that need to be taken into account. For example, Wijgerse (2007) stated that increased energy access is beneficial, but that the system that was analysed in Tanzania needed improvements such as a clear ownership and maintenance structure, the installation of household electricity meters and the adoption of high efficiency lights. Broadhurst (2011) compared a plantation, a smallholder (outgrower) model and a community model and concluded that all three can increase income and employment. However, if a plantation scheme is aimed at the export of the raw material, local energy security is not improved.

Poverty/local economy

The study by Peters (2009) analysed the impact of a jatropha plantation in Mozambique on the households of its employees. It found that households working on the plantation had better socio-economic conditions than households in the control group (Peters 2009). In addition, the study concluded that the income and expenditures (significant for food and non-food items) increased and leisure time decreased. Microenterprise activities and the sale of cash crops increased too. In schemes in Honduras and Mali, farmers are shareholders of the biofuel company; if profits are made by the company they will be returned to the farmers (Moers 2010). In Honduras a local currency was introduced by the project, with the objective to stimulate the local economy (Moers 2010; Prakash 2012). This local currency was used to buy biofuel, to buy from each other, to partially pay wages or was converted back into the national currency. The study by Portale (2012) revealed that the perception of economic access to credit is higher among outgrowers than non-outgrowers, probably due to the belief that a contract will create ways to access credit. The study by Arndt et al. (2009) differentiated between outgrowers and plantations and concludes that the first system is “more pro-poor due to the greater use of unskilled labor and accrual of land rents to smallholders.” Mujeyi (2009) indicated that wealthier households do not farm jatropha; in fact, it seems to be a crop for poor farmers. This finding is confirmed by (Mponela et al. 2010). In contrast, Bos et al. (2010) observed in Mozambique that the wealthier farmers have more room to experiment and were therefore more likely to adopt jatropha. The study by Broadhurst (2011) indicated that a smallholder system creates an enabling environment for local farmers and entrepreneurs. Several studies have indicated low financial benefits from jatropha (GTZ 2009b; Van Eijck et al. 2013). So far, this low profitability has led to a relatively low impact on poverty levels. However, there may be other positive effects on livelihoods. Schoneveld et al. (2011) mentioned that the majority of respondents (67%) who felt that their livelihood had increased due to the jatropha plantation did not consider their increased income the most important, but rather the increase in security and stability of income flows.

Employment generation

Employment levels vary according to the business model used. The efficient agricultural management systems used in plantations usually generate more employment, while smallholder models reach more people although their less efficient management leads to smaller economic benefits per person (Van Eijck et al. 2013). Habib-Mintz (2010) observed that most jobs created on plantations were for land clearance and land preparation, which are tasks that are only required once. From an analysis of investment proposals in Mozambique, it was calculated that the jatropha companies estimate a job creation of 0.14-0.17 jobs per hectare. While the total investments for these jatropha projects equal almost 3 million $ or 1,700 $/ha. One formally approved jatropha project in Mozambique provided 0.27 jobs/ha including seasonal labour (Schut et al. 2010b). The company Diligent in Tanzania had around 200 seed collectors working for them in 2009 (Gordon-Maclean et al. 2008).

Skills

In Mozambique it was observed that on the job training took place for skills such as pesticide spraying and tractor driving (Schut et al. 2010b). However, of the nine projects visited, not one provided formal training or education programmes. In Honduras local people were trained in the production of biodiesel, although external experts were needed for this training (Moers 2010). In addition, fifteen car mechanics received training in adapting engines. Moers (2010) also observed that a degree of technical capacity is necessary in order for jatropha projects to become successful. Prakash (2012) pointed out that in the six projects she evaluated, dissemination and implementation of agricultural knowledge was problematic due to extension workers without proper training and a lack of clarity among organisations about their responsibilities. Furthermore, the ratio extension workers to farmers was very low.

Attitudes and well-being

Unmet expectations and initial misinformation may lead to a decline in trust. This has been reported in 5 cases in Myanmar, Mozambique, Mexico, India and Kenya. In Myanmar people became cynical when the expected benefits did not materialise, this was probably due to a lack of proper information on agronomy and the market (Ethnic Community Development Forum 2008). De Jongh and Nielsen (2011) indicated a lack of trust due to the collapse of the jatropha seed price over time in Mozambique. Initially, the price of seeds was artificially high because the establishment of new plantations led to a high demand for seeds, which decreased significantly at a later stage. Also Skutsch et al. (2011) indicated that too high initial expectations led to a subsequent decline in trust in Mexico. In India, 85% of farmers discontinued because jatropha had not met their expectations (Axelsson and Franzén 2010). Moreover, misinformation, often at the start of a project, leads farmers to lose faith in the information they receive and in the organisation that supplies it; this is what happened in Kenya (GTZ 2009b). This misinformation at the beginning of projects was not necessarily intentional, but there is still a great lack of knowledge about agronomic practices (Jongschaap et al. 2007; GTZ 2009b).

Portale (2012) addressed well-being by looking at life satisfaction and evaluating happiness. This revealed that jatropha outgrowers score higher on these indicators, which is probably the result of better household living conditions caused by jatropha sales. In addition, social capital (based on trust and participation in projects) was higher among outgrowers. However, in the village in which these benefits were observed, jatropha had been cultivated for a long time and relatively high prices were being paid, which may also have contributed to the positive ratings.

Many projects have had, or are expected to have, a positive influence on several aspects of local prosperity, whereas almost all negative impacts on local prosperity are due to discontinuation of the projects. This leads to the conclusion that financial feasibility of jatropha projects is essential for local prosperity.

Methodological aspects

Most studies were based on interviews and observations. For example, the study by Loos (2008) investigated agricultural income, land, livestock and assets to measure welfare. However, this can only result in quantitative impact data if these data can be linked to biofuel projects, requiring at least several measurements over time. There were also studies based on potential impact rather than on actual observations. The impact on local prosperity has only recently been partially modelled or quantified for example by Van Eijck et al. (2013). They considered wages and employment in relation to unemployment rates in the region, total investment costs, local purchases, relation of local versus non-local employees and also qualitative indicators for social well-being and the risk of negative impacts in the case of project failure. Portale (2012) combined several qualitative questions in her survey into an economic access index, a well-being index and social capital score, which together provide insight into the perceptions of the smallholders. Arndt et al. (2009) used CGE modelling to link several aspects of poverty, which led to the conclusion that biofuel production schemes that include outgrowers generate more employment for unskilled labour. Furthermore, technology spill-overs especially can enhance economic growth and poverty reduction.

Quality judgement and knowledge gaps

The exact impact of the jatropha projects on local prosperity is difficult to gauge as this relationship is rather complex. Comprehensive methodologies are required that combine the most important variables regarding local prosperity, such as the impact on employment, income, investment in the region, labour migration, possible risks for local communities and the attitude of the local population. The methodology should also include possible employment displacement effects of plantations, and changes in income or wealth. Applying a regional input-output methodology may assist in identifying the monetary impacts of the biofuel sector on a region (e.g. (Herreras Martínez et al. 2013a). However, it is necessary that regional input-output tables are available. Furthermore, the early overly optimistic yield estimates led to misinformation at the beginning of several projects. Agronomic data should be reported more accurately and completely, including soil quality, precipitation and age of the trees.

5.5.3.3 Labour and working conditions

Eleven studies covered aspects of labour and working conditions. They are summarized in Table 5A-10 in the Appendix. Five studies came to a positive conclusion, two found no effect and four found negative impacts of which some only found anecdotal evidence. Four aspects were frequently mentioned: legal issues, wages and other benefits, child labour, and health and safety. They are described in further detail below.

Legal issues

No studies observed any by-passing of the law without consequences. In Mozambique the government voided one contract when contractual obligations were not met: the business plan was not followed (Schut et al. 2010a). A weak position of smallholders is mentioned by one study (IFAD/FAO 2010) and there is one case in Myanmar where farmers were allegedly forced to grow jatropha; however, this claim could not be verified (Sheng Goh and Teong Lee 2010) (Ethnic Community Development Forum 2008).

Wages and other benefits

Schut et al. (2010b) found that all nine companies visited in Mozambique paid at least the minimum wage. Chachage and Baha (2010) observed that of 600 jobs only 90 were permanent. Since jatropha harvesting is seasonal, this is an important issue. Smallholders would like to see higher seed prices but at the same time jatropha companies that process the seeds offer additional benefits to their employees such as National Social Security Fund, medical and funeral support, credit and savings society training, courses and meals (Gordon-Maclean et al. 2008; Van Eijck 2009). The study by GTZ (2009b) indicated that only fence cultivation is profitable for smallholders. Transport for non local workers could be improved in some cases (Schut et al. 2010b). At the plantation of Energem in Mozambique, 500 jobs were created, paying at least the minimum wage (60 $) and ending the workday early to enable workers to tend personal fields. However, although meeting the minimum wage requirement, salaries were still too low to allow workers to improve their standard of living (Ribeiro and Matavel 2009). Peters (2009) identified a large difference between two plantations in the number of days absent. This might be due to the higher job opportunities in the area where the higher absenteeism occurred. Thus, wages could be insufficient to cover opportunity costs. Moreover, the ratio male/female is much higher at this plantation. The study by Ariza-Montobbio and Lele (2010) observed that landless and marginal farmers in India normally migrate to nearby cities after the agricultural season. However, due to the low labour demand related to jatropha, the perennial characteristics of jatropha, and the potentially low financial benefits, these farmers now stay longer in the city to work as daily wage labourers. The company ESV in Mozambique employed 1350 workers and paid the permanent staff above minimum wage. Nevertheless, due to the financial crisis, they were not paid for nine months before the company was taken over. Two other companies in Mozambique, Mocamgalp and Sun Biofuels, employed 35 and 430 workers, respectively (in 2009), although the latter company apparently had nine-hour workdays, which is legally not allowed (Ribeiro and Matavel 2009).

Child labour

In smallholder communities, it is common that children help with farm tasks; it is likely that this will include picking and dehulling jatropha seeds (Mitchell 2008a; Van Eijck 2009; Bos et al. 2010). In the processing companies or on plantations, no child labour has been reported. Workers have to identify themselves so that their age can be verified (Schut et al. 2010a).

Health and safety

Not much has been observed about aspects of safety in the current projects. Brittaine and Lutaladio (2010) (IFAD/FAO) and Proforest (2008) mentioned potential poor conditions, but these were not actually observed. In addition, Chachage and Baha (2010) mentioned some anecdotal stories of bad working conditions from employees of a plantation company. However, these do not seem to have been verified[21]. Safety gear is usually provided, but in one case in Mozambique a difference was observed between permanent and casual labourers, where the latter group did not receive any safety gear (Gordon-Maclean et al. 2008; Schut et al. 2010b).

Health issues mostly relate to the toxicity of the seeds and the oil. Janssen et al (2009) found no evidence that the use of jatropha oil results in the emission of specific toxic compounds in health-affecting quantities; however, this was the only study that reported on this. Not all aspects seem to have been researched; for example, the impact on the skin has not been investigated. There are some studies on the toxicity of the seedcake. The toxic compounds (phorbol esters) of jatropha press cake degrade within 15-23 days when applied to the soil (Devappa et al. 2010). Another study by D1 Oils concluded that no toxic compounds could be traced in the chemical analysis of food crops fertilised with jatropha seedcake (Van Peer, personal communication). So far, no negative health effects have been reported other than the direct effects of seed intake, but this may be due to a lack of long-term studies.

Other issues

Differences in work ethics were observed in Mozambique between the (foreign) investor and local workers. These differences occur both on plantations and in contract-farming arrangements. Labourers did not show up for work after payday, and farmers did not honour their sales contracts because they were not used to working on a contract basis (Schut et al. 2010b).

Moreover, Nielsen and De Jongh (2009) observed that the peak in labour demand for jatropha coincides with the peak in demand for food crops. Still, jatropha seeds can be left on the tree for several weeks, which makes it possible to harvest jatropha after the peak labour demand for food.

[21] The report mentions a case in which an employee supposedly contracted tuberculosis from the smoke in the company's cooking area. However, this disease cannot be contracted by inhaling smoke.

Methodological aspects

The studies have a similar set-up: they are all based on interviews and observations. Therefore, the fact that some mention positive effects and others negative ones cannot be attributed to different research methodologies. However, the number of observations varies, and some reports base their conclusions on what seem to be incidents. Interviews and observations are a good way to assess labour and working condition issues because differences are local and depend on the specifics of project implementation. Some reports also provide recommendations for improvement, which could help other projects.

Quality judgement and knowledge gaps

Since working and labour conditions are project-specific, monitoring of the projects is necessary, which is what most studies do. Notwithstanding the good intentions at the beginning of a project, it is necessary to incorporate a proper exit plan in the approved business model, especially to prevent mishaps after discontinuation. So far, a proper exit plan has only rarely been drawn up. National laws mostly include aspects of working and labour conditions, so it is essential that projects ensure that they comply with national (and international) laws, and most projects seem to do so.

5.5.3.4 Land ownership and land rights

Land conflicts are very common in developing countries, especially in Africa. Many studies have been published on this issue, although they mostly do not focus specifically on jatropha but more generally on land deals in Africa in relation to biofuels (e.g. (Cotula et al. 2008; Cotula et al. 2009; Sulle and Nelson 2009a)). In total, 23 jatropha studies assessed or mentioned land ownership aspects; these are presented in Table 5A-11 in the Appendix.

Almost all studies listed in the table indicate negative or neutral impacts. Only one indicates a positive impact, namely that hedge planting can reduce boundary conflicts. There are some recurrent issues associated with obtaining administrative land rights of large plots of land. They include: unclear acquisition processes, tenure conflicts between customary and granted land rights, disputes over compensation payments (and over unclear methods), misunderstandings about exact land demarcations (in absence of adequate and coordinated land information), poor communication between the new land owner and local communities, a lack of understanding about employment opportunities, and a lack of transparency of the whole process, which creates confusion (Gordon-Maclean et al. 2008; ProForestLtd. 2008; Altenburg et al. 2009; Sulle and Nelson 2009a; FAO 2010a; Habib-Mintz 2010). These issues are in part due to pre-existing issues;

boundaries are often not clearly defined and land ownership is generally not documented (Weyerhaeuser et al. 2007; ProForestLtd. 2008). Furthermore, idle or marginal common lands often provide various products and sources of income for the rural poor (Altenburg et al. 2009; Estrin 2009). Another issue is the often very long-term lease contracts, in some cases as long as 99 years (Gordon-Maclean et al. 2008). It is challenging for the local population to take in such a long period and it is also difficult to put an accurate value on land for such a long period.

Large land ownership transfers or land lease contracts are often accompanied by promises about the provision of goods and services, such as infrastructure and classrooms. However, the studies have reported several problems. Often, such promises are only made verbally by the land owners, and after a project is discontinued, no further development of the area occurs. Land access is also often unclear after project discontinuation (Mwamila et al. 2009; Ribeiro and Matavel 2009; Chachage and Baha 2010; Schoneveld et al. 2011; Van Eijck et al. 2013); see also Appendix B. In some countries, such as Tanzania, land rights are first transferred from the villagers to the government before the rights are transferred to the company that will plant jatropha or another crop. After discontinuation, these rights are not transferred back to the villagers, although the expected development in the area does not materialise (Chachage and Baha 2010; Van Eijck et al. 2013). Not many observations were done on resettlements, two studies in Mozambique mentioned voluntary resettlement in order to be closer to the workplace, and a study mentioned an initial displacement of 950 households which would drop to below 150 if they planned cultivation differently (Andrew and Van Vlaenderen 2010; Schut et al. 2010b).

In smallholder systems with no administrative land rights exchange, land issues are much less dramatic than in plantation systems in which landownership changes. However, 93% of the jatropha growers in Tanzania responded that it is difficult to extend their land under cultivation (Mitchell 2008a). This was also observed by Wahl et al. (2009). The studies mentioned the following reasons: customary control, a general reluctance to sell land, a shortage of suitable land and an increased population. However, in another study on Tanzania by Loos (2008), of the 117 non-jatropha farmers interviewed, only 1.7% responded that a lack of land was the reason for not growing jatropha. A study in Mali concluded that land access did not change as a result of small-scale growing of jatropha (Salfrais 2010). A similar conclusion was drawn in Mexico (Skutsch et al. 2011). Differences in land access were perceived to be related to indigenousness, gender and seniority of the villagers. Land pressure was identified as an important reason for problems with land access. Increased land pressure could lead to vulnerable groups losing their land access or having difficulty in sustaining their land access (Salfrais 2010;

Schoneveld et al. 2011). Several studies indicated that planting trees is seen as claiming land ownership, which may increase conflicts (Spaan et al. 2004; Practical Action Consulting 2009; Salfrais 2010). The pastoralist Masaai tribe in Tanzania consider the large-scale growing of jatropha as upsetting their traditional lifestyle (Laltaika 2008). On a smaller scale, planting jatropha as a fence can also help to reduce land boundary conflicts, especially if the neighbours are involved when the lines are delineated (Salfrais 2010). Studies advising hedge planting include Wahl et al. (2009) and (GTZ 2009b).

Some studies mention alternative land ownership structures; for example, in India there are self-help groups that have exclusive harvest-rights instead of land rights (Wani et al. 2006; GRAIN 2008). In addition, a study by Brittaine and Lutaladio (2010) mentioned an example in India where degraded community lands were rehabilitated by planting jatropha. The strategy involved the use of degraded common property resource lands held by the village council. Self-help groups of landless people and smallholders were paid per workday as an employment creation scheme. The land and trees remained in public ownership.

Methodological aspects

Most studies were based on interviews and observations. This is understandable since there are hardly any other data available, such as court records of the number of complaints. In developing countries, bodies where communities can complain are often not well established. Some studies express a very negative sentiment, using phrases such as 'land grabbing' and 'land take-overs'. Some studies researched the amount of land available by analysing national or regional statistics (Schut et al. 2010b). However, no future projections of land pressures were included that take population growth and future food needs into account. Assessments of changes in land access (as compared to land availability) are more subjective and these changes are not well-recorded.

Quality judgement and knowledge gaps

The observations in the studies suggest that most of the problems with land acquisition and land rights are due to weak institutional frameworks and pre-existing problems with the governance of land rights and land ownership. For example, there are often no clear rules for compensation payments. A process of land acquisition is time-consuming and it takes a great deal of effort to make sure that the local population clearly understands the contractual arrangement and is sufficiently informed during the negotiations. A transparent process and optimal communication with the local population are essential. Vulnerable groups could more easily lose their land rights; therefore, these groups should be considered specifically. Studies should include various stakeholders if they want to document the process of land acquisition. More research is necessary into finding measures to mitigate reduced land access. Comprehensive analyses that take population growth into account help to assess whether and where there is sufficient land available in the future; this depends on several issues, including cultivation intensity.

5.5.3.5 Gender issues

So far, gender issues for jatropha have not been considered in great detail. Only four studies include a specific analysis of gender related aspects, namely Mota (2009), Peters (2009), ENERGIA (2009) and Arndt et al. (2011), although the ENERGIA study does not exclusively consider jatropha. Other studies have observed gender differences but have done so as part of a broader analysis framework comprising multiple aspects. A total of 11 studies have covered gender-related aspects; they are presented in Table 5A-12 in the Appendix.

Most studies conclude that the production of jatropha has no effect on gender equity (so far), only two found a negative impact and two found positive impacts. Negative impacts (mentioned in the two studies) are due to pre-existing gender differences, namely the fact that it is women who cultivate food plots and have domestic tasks. Working as an employee on a plantation reduces the time available for these tasks, which still need to be fulfilled (Mota 2009; Peters 2009). Although in Mozambique, it was observed that favourable working hours at the plantation enabled women to keep tending their household food plots (Peters 2009). A calculation by (Arndt et al. 2011), shows that also yield improvements can offset the effect of reduced food production by women. Positive effects are related to increased energy access, which reduces women's tasks, such as collecting firewood and milling maize.

It remains unclear whether increased energy access leads to increased gender equality. A study by Verhoog (2010), which did not specifically focus on jatropha, suggested that women's empowerment is not automatically improved if access to energy is increased. This is only the case if the project specifically focuses on the empowerment of women. This last point is confirmed by Clancy et al. (2004). Nevertheless, the study by ENERGIA found that projects that increased energy access automatically improved the lives of women. One case study in that publication mentioned that women could charge their batteries in the village. In the past, batteries could only be charged with the help of a male relative since the charging point was 20 km away and women do not own bicycles or motorcycles in rural Cambodia (2009).

De Jongh and Nielsen (2011) did not specifically analyse gender aspects but they do mention two studies that found no gender bias in the adoption of jatropha. However, they also state that these studies were based on only a few interviews and that more comprehensive studies are required.

Possible gender problems that can be associated with the production of liquid biofuels in general were described in a study by the FAO (Rossi and Lambrou 2008). From other sectors, they found documentary evidence that gender gaps occur, for example due to the lack of access to resources for women. Land ownership is often more difficult for women, and related to this, access to credit, because women do not have land that they can offer as collateral. Furthermore, if energy crops are planted on marginal land, this has a greater risk of pushing out women, since they are mostly the ones who collect commodities such as firewood from these grounds. Although the interviews conducted by Salfrais (2010) revealed no worsening in the situation of women's land access after jatropha cultivation started in Mali, she stated that this may change in the future. Increasing land pressure increases the risk that women as well as other vulnerable groups (non-founding families and younger members of the community) lose their land access rights. In one case, a men's association pressed the women's association to discontinue cultivating one hectare of jatropha, which shows that men have control over land access (Salfrais 2010). In some countries jatropha cultivation is carried out by men, in others by women or by both. It is also very common that older children help with farm tasks. In Mali, women traditionally extract oil from jatropha for medicinal purposes (Brittaine and Lutaladio 2010). In Mexico, jatropha cultivation and seed selling are considered a man's business, whereas dehulling, which is quite an arduous task, is performed by women (Skutsch et al. 2011).

Women (and children) often pick seeds. In Zimbabwe, women are also involved in soap and candle making, which to some extent has led to empowerment because it generates extra household income (Tigere et al. 2006). Henning indicated that in Mali, men initially allowed women to harvest seeds for soap making, but when the women turned this into a cash-generating activity, the men wanted a share of the profits. This led to some loss of interest in the project since the project goal was to promote women's participation (Henning 2004 cited in (Brittaine and Lutaladio 2010). This mechanism of appropriation by men is also described by (Brew-Hammond and Crole-Rees 2004)). If plantation owners pay on a piece-rate basis, this can discriminate against women if the job requires physical strength. Plantation owners sometimes tend to prefer women workers because they feel they can pay them less (Rossi and Lambrou 2008). The study by Arndt et al. (2011) showed that skills-shortage among female workers limits poverty reduction, and policy should therefore be addressed to increasing women's education. A study by Portale (2012) concluded that women decide which crops to grow in only 25% of the households.

Methodological aspects

Almost all studies were based on interviews and observations, and only one was based on a model that includes several aspects. This study, by Arndt et al. (2011), looked at gender implications for (jatropha) biofuel production with the help of a gendered CGE model. Portale (2012) constructed a gender index by asking the respondents (201) who was responsible for the household crop decisions. Both men and women had to answer, and this revealed no difference, which led to the conclusion that the rate was similar to the national average.

The main gender differences observed in the studies seem to be derived from pre-existing gender differences. There are some similarities but also differences among the countries under study. For example, farming activities are a task for women in Mozambique (Mota 2009). This then translates into jatropha cultivation also being performed by women as observed in the same study; only women labour was used for farming jatropha in 62 out of 70 households. In contrast, Tanzania farm labour and jatropha cultivation are performed by both men and women (Mitchell 2011).

Quality judgement and knowledge gaps

So far, gender aspects have not been well analysed for jatropha projects. There is a lack of long-term studies that systematically collect gender-disaggregated data. Moreover, evaluations of energy projects very rarely use gender analysis, something which had already been noticed by Clancy et al. (2004). Nevertheless, there are more general gender studies that include analyses of the effects of biofuel production.

5.6 Discussion and knowledge gaps

Table 5-4 summarises the economic, environmental and social aspects that have been covered well by current literature, as well as those that have not yet been covered well. The methodologies applied by the studies are also indicated in the table, and remarks are made on any shortcomings.

Table 5-4: Literature coverage and knowledge gaps on socio-economic and environmental issues, and an overview of applied methodologies

Aspects	Methodologies applied	data availability	Remarks
Economic aspects			
Cost benefit analysis	cashflow accounting methodologies (IRR, NPV, pay back indicators)	Mainly estimates or extrapolations	More analyses based on real data are starting to be published. Still, the assumptions have a high degree of uncertainty.
Set-up, running and processing costs (SVO, biodiesel, briquettes)	Analysis with business proposals	Very difficult to acquire	Not publicly available, companies do not share data, and no large amounts are currently processed.

Yield / seed sales revenue	Literature and observations (not long term)	Extrapolation of data based on short term and specific locations	Very anecdotal information, long term studies on agronomic practises ongoing
Value of by-products	Estimated or observed (few cases)	Hardly available	Market still not developed, necessary to find higher value by-products
Environmental aspects			
Climate change (GHG balance)	LCA methodology (different tools available)	Data on processing is available, carbon stock data as well but LUC location specific data often lacking	Still based on many assumptions. Data is especially lacking on acidification, eutrophication and nitrous oxide emissions and how to minimise these. Findings from studies are hard to compare, mainly owing to differences in boundary and fossil base-line assumptions and differences in treatment of Jatropha by-products,. Also depending on the specific LCA tool that is used. Treatment of land use change (LUC) impact on GHG either missing or taken into account by using a lower and upper boundary.
Nitrogen contributions to GHG	Calculations based on estimates	Hardly available	Are only partly included
Biodiversity	Observations, estimates, field measurements (including satellite measurement)	Only very site specific, more data required	Impact of jatropha is unknown, relation between intensity of production versus biodiversity is unknown. Land use change important, so far inadequately taken into account.
Social aspects			
Food security	Interviews, observations, analyses of background information (statistics) and CGE modelling.	Anecdotal information and back ground data is available	Studies are required that link availability, access, stability and utilisation and quantify and predict these impacts.
Local prosperity	Interviews, observations, analyses of background information (statistics), CGE modelling and design of (wellbeing) index based on primary survey data.	Anecdotal data available	Impact on different aspect signalled: local use, employment, impact on local economy, skills, attitudes. Studies that quantify the impact on local economy are hardly available.
Labour working conditions	Interviews and observations (nr of	A reasonable amount of data	Aspects of child labour, discrimination, safety, freedom

	observations vary).	available, project specific	of trade union, education and training. Well documented, by means of company documents and national laws. Monitoring necessary by objective body.
Land rights (land availability and access)	Interviews, observations, analyses of regional statistics.	Large amount of literature available on the context	-Studies that include future projections on land availability are required. -Studies that look at measures to mitigate reduced land access are required.
Gender	Interviews, observations, gendered CGE model, design of (gender) index based on primary survey data.	Almost no gender disaggregated data available	Gender analysis in the evaluation of energy projects are lacking.

Economic aspects: assessment

There are still many gaps in the information about economic issues. CBAs have been undertaken for smallholders (1 ha plantations, and some intercropping set-ups and hedge plantings), and a few from a national (macro) perspective, without making any specific reference to business organisation and production sizes. For large-scale plantations, CBAs are much less available (e.g. in Van Eijck et al. (2013) and Hardman&Co (2011). Private companies have also undertaken CBAs, but these are not publicly available. The majority of CBAs rely on unreliable and often unrealistic yield data that do not match the findings about observed yields (1000-2000 kg dry seed ha/y for mature plantings). CBAs often take a time horizon that is too short (10 years or less) to be able to reliably assess the long-term average jatropha viability. There is a general lack of information outside the Eastern/Southern African and Indian context, although in part this is due to the lack of studies in Spanish and other languages besides English that have been taken into account in this assessment. Data on the financial viability of plantations are almost completely missing and not many plantations are in full operation, although there are some data about their establishment costs and running costs. There are also hardly any studies that systematically compare the financial feasibility of outgrower schemes and centralised plantations of similar production volume or land area (only (Van Eijck et al. 2013), and (Broadhurst 2011) to some extent). Data about the cost of SVO and biodiesel production in facilities of different scales are scarce, especially in Africa where commercial oil production is only just beginning.

Environmental aspects: assessment

Additional research is required to fill in the knowledge gaps on environmental aspects by studying land use change, including the effects from above ground, below ground biomass and soil-bound carbon and nitrogen on initial carbon debt. Lal (2010) claims that terrestrial pools of carbon can act as a sink for atmospheric $CO_{2.}$ Optimally managing the soil carbon pool must be the basis of any strategy to improve and sustain agronomic production, especially in developing countries. George and Cowie (2011) point out that soil organic matter (SOM) strongly influences many soil properties and as such is a primary indicator of soil health. The amount of SOM in soil is a function of climate, topography, parent material, biology and time (Rice, 2005, in (George and Cowie 2011). Loss in soil carbon in the establishment of energy crops, or as a result of residue removal, could negate the climate change benefits of using bioenergy to displace fossil energy sources (Fargione et al., 2008, in (George and Cowie 2011).

Moreover, more reliable data is needed to gain better insight into trade-offs and related impacts, for example using marginal land with increased fertiliser versus using more fertile land, adopting large-scale centralised processing with long feedstock transport distances versus centralised small-scale production and local use, and using seedcake for fertilisation versus using seedcake for energy use. Not many studies have analysed the impacts on biodiversity and baseline studies are lacking as well as long-term impact studies. So far, no quantitative research about the soil erosion prevention capacity of jatropha has taken place (Achten et al. 2007).

Social aspects: assessment

The knowledge gaps on social aspects are on food security. Comprehensive studies on food security that include all four aspects defined by the FAO are not well covered (food availability, access, stability of supply and utilisation of food). Studies that examine the relationships between these different aspects are especially lacking. Regarding local prosperity, hardly any information has been found on local employment for smallholders or impacts on the local economy. Labour and working conditions on plantations have been documented quite well by company documents and studies that include field observations, although it is still unclear as to what extent plantation workers actually develop skills. National and international laws seem to prevent most negative impacts (e.g. on health), although monitoring remains necessary. Land rights issues mostly emerge due to pre-existing problems; the acquisition of large amounts of land for biofuels can bring these latent issues to the surface. More studies are required that include measures to mitigate reduced land access by communities. Moreover, studies that include projections on population growth can assist governments or communities to make sure they maintain enough land for future food production. To properly assess gender issues, gender-disaggregated data is required on e.g. employment, energy access and so on.

In this analysis, country-specific issues are not covered; these include political and institutional issues, land availability, culture and climate. Some other issues only came up in individual countries, for example in Mozambique. In this country, Schut et al. (2010a) observed that most biofuel companies aimed at being located in places with a good infrastructure, high population density and good agricultural conditions. This means the rural population may not be targeted. However, because so many different projects and countries are analysed in the study, the majority of the lessons and recommendations can be used in multiple countries. So, although e.g. the number of studies that covered Latin-America was limited (due to a lack of published studies in English and the limited amount of ha planted), the project set up is not very much different from the set up in the other continents and therefore the lessons and recommendations in this assessment can be applied generically. Whether or not biofuels are stimulated and facilitated by the government makes a large difference in the potential success of biofuel projects (Gordon-Maclean et al. 2008; GRAIN 2008; Rajagopal 2008; Martin et al. 2009; Ndong et al. 2009; Sheng Goh and Teong Lee 2010). These studies conclude that there is a need for biofuels to be integrated within a broader framework of investment in rural infrastructure and human capital.

In this assessment two business models were identified and analysed separately when possible. However, there are more models that may be used in bioenergy projects. A distinction can be made between models that describe production systems, such as hedge cultivation, plantation or a mixture, and those that describe the organisation, for example government, farmer or corporate centred or multipartite (joint venture between state, private company or NGO and farmers), there are also combinations (e.g. nucleus estates) and informal models (Altenburg et al. 2009; Bijman et al. 2009; van Baren 2009). Studies including Bijman et al. (2009), Van Baren (2009) and Vermeulen and Cotula (2010a) describe possible models for smallholders and the problems that could be encountered, namely high costs and risks, and market uncertainty. Furthermore, in India there are self-help groups, described by Wani et al. (2006), and in Honduras a model is used in which farmers own a share in the processing company, described in (Puente-Rodríguez 2009; Moers 2010). As yet it is unclear what the performance is of these and possibly other business models that have already been or could still be developed. More research is required on the various types of business models and their impact.

5.7 Conclusions

Despite various methodological drawbacks in the studies covered in this review, it can be concluded from this assessment that current-generation jatropha projects are barely financially viable and some may even operate at a loss. This is especially true for plantation settings and is mainly due to the higher input intensity of plantations combined with still limited yield levels and limited valorisation of by-products. It has also become clear from this review that financial viability for smallholders can only be achieved if limited inputs are used and if opportunity costs for labour and land are low. In the longer term, yield increase to above 2-2.5 ton/ha/yr (the reported technical maximum is 7.8 ton/ha/yr) is necessary as well as improved value addition of by-products such as seedcake and glycerine, which may be used in the production of energy, fertiliser, soap, bio-pesticide, and other products. The methodological drawbacks that have been found in the studies, such as no full CBA analysis, lead to large differences among the studies. The largest profitability differences found among the studies are due to variations in seed yield (3000-7000 kg/ha/yr), discount factors and time frames that were chosen, and whether land and labour costs were fully included in the cultivation cost calculations.

Environmental impacts have been found to vary greatly per location, but in general plantation schemes have a higher risk of pervasive impacts than smallholder projects. Most studies (26 of 38) indicate a significant GHG benefit over fossil fuels. An additional 11 of these 38 studies concur, provided limited inputs are used and there is no loss of high carbon stock, which is possible if jatropha does not replace forest land or biodiversity hotspots. However, it should be noted that most studies in the environmental category focused one-sidedly on energy and GHG balances and often did not incorporate complex aspects such as land use change effects. So far, more indirect effects of jatropha seed cultivation, for example the disruption of nutrient cycles, have not received any attention either. Three studies reported a loss of biodiversity (in Brazil, Mexico and Tanzania); this was found to be caused by deforestation. Conversely, planting jatropha as an addition to current land cover can also help regenerate soil conditions and may increase biodiversity.

The analyses of social aspects have revealed minimal negative impacts from ongoing projects so far, but discontinuation of projects clearly affects the local communities, not only through loss of income and uncertainty of land re-access, but also through a more negative attitude towards new projects. However, non-financial benefits, such as employment security, training possibilities (both for skilled labour and for smallholders), an increased sense of connection to 'foreign' projects, fostering openness to change, and a possible increase of energy security, are considered important by many local parties. Therefore, if financial feasibility can be increased, jatropha cultivation can be regarded as an opportunity to realise social development goals for workers and smallholders. Communities in regions suitable for jatropha are often vulnerable; for example, food security is often already problematic, leaving little room for failure. Therefore, projects are needed that reduce the risks for these smallholders, for example by offering an additional cash crop (e.g. from hedges or from hitherto unproductive land) or improved energy access.

For jatropha to become a viable biofuel in those markets, its whole value chain needs to become more profitable. It has already been emphasised that there is a need to find higher-value uses for by-products (especially seedcake). Other important ways forward include achieving greater oil-processing efficiency, developing seed varieties with higher and more reliable seed yields under semi-arid conditions, and optimising cultivation practices. These challenges require sustained effort over longer periods of time.

This assessment found that there are still many gaps in information and knowledge, and also a lack of consistency in data collection. Most data found in the studies was hard to compare because it was based on different methodologies (energy balance versus GHG reduction) or used different assumptions (for example regarding discount rates, yields and planting distance), and gave values in different (functional) units (for example electricity production in the Netherlands versus 1 ton biodiesel produced). The studies should provide more extensive information about which methodology was used, be more explicit about their choices and assumptions, and indicate the sources or information that their conclusions are based on. Moreover, the lessons learned from the projects are fragmented and there does not seem to be a great deal of exchange between projects. In addition, authors do not frequently compare their results with those of other authors. Information sharing and benchmarking practices could assist the entire jatropha community to better understand the underlying causes of the large variations and at times contradictions in the findings.

Methodologies to analyse economic aspects are available, for example cashflow accounting using NPV, IRR and Cost Benefit Ratio indicators. However, the data necessary to perform these calculations is often missing. There are also various methodologies for assessing environmental impacts; LCA methods including or excluding land use change have been developed, and these are now available specifically for the assessment of jatropha biofuels. However, again, the field data required for accurate calculations (of for example a GHG balance) is difficult to obtain since this data varies by location. For social issues, most methodologies have been based on qualitative data such as (sometimes limited) observations and interviews. This could be sufficient to determine for example working and labour conditions or the status of land ownership and land rights. Still, for the assessment of food security and local prosperity, it would be preferable to have comprehensive frameworks that can quantify impacts (e.g. through simulation modelling). However, so far methodologies to quantify the impact of these factors have hardly been developed.

5.8 Recommendations

Our recommendations have been grouped by addressing three groups of stakeholders: researchers, project practitioners and government bodies.

Researchers

- More data should be collected about the expected profitability, and more reliable, observed yield figures should be used to conduct CBA assessments.
- Research should focus on improving profitability by finding higher-value uses for by-products, achieving greater oil-processing efficiency, developing seed varieties with higher and more reliable seed yields under semi-arid conditions, and optimising cultivation practices.
- More research is required to gain better insight into trade-offs and related environmental impacts, for instance using marginal land with increased fertiliser use instead of more fertile land.
- Accurate and complete reporting on scientific measurements can assist in creating realistic expectations.
- All linkages and aspects related to food security should be analysed to arrive at a greater understanding of the food security impacts caused by plantations.
- The impact on labour conditions should be monitored as employment is being scaled up.
- Quantitative analyses are required to gain better insight into the impact on local prosperity.

Project practitioners

- An independent mediator should be involved in land acquisition processes.
- Land pressure should be taken into consideration before activities in a certain region start.
- It is necessary to experiment with alternative business models, in which the community is a business partner.
- Suitable working hours should be provided so that (female) workers can tend their household food plots.
- Attention should be paid to fair pay, the inclusion of gender in project design, women's training and education and early involvement of women in projects.
- Realistic expectations for example on yields should be disseminated.
- Jatropha should not be planted on grounds where it replaces common property areas on which the local population collects fuel wood and fodder, or projects should include viable alternatives for the loss of these resources, for example wage income and biogas.
- Local purchases (of for example food, drinks and construction materials) should be encouraged in order to ensure that a large share of companies' investments stays within the region or country.

- Deliberate attempts have to be made to ensure that plantations create technology spill-overs, through training and education.
- Local populations need to be provided for in case companies stop their activities, for example by ensuring that local food plots are not neglected and that land access should not be decreased without compensation after discontinuation.
- Investors themselves should consider a gradual upscaling strategy, to enable gradual learning-by-doing without overstretching their finances and organisational capacity.

Government bodies

- Economic sustainability (financial viability) should be included in biofuel sustainability certification schemes, which is currently not the case.
- An exchange between the projects of any lessons learned should be promoted to prevent similar pitfalls.
- Zoning regulations for large land-based investments may need to be introduced and observed. Incentives should be provided to promote investments in remote poor rural areas.

Acknowledgements

This study was partly funded by NL Agency in the framework of the Global Sustainable Biomass Programme. The authors would like to thank Kees Kwant, Carmen Heinze and Sietske Boschma for their support. Furthermore, we would like to thank Edward Smeets and Raymond Jongschaap, who worked with us on earlier versions of the study.

5.9 Appendix: Tables with analysis of the studies per area of concern

Economic aspects

Table 5A-5: Studies that include a financial or economic analysis and their main conclusions on financial viability (organised by year).

Study	year	sm	pl	Pos-itive	Neutral	Neg-ative	Country of study, setting (if available) and main outcome
(Openshaw 2000)	2000	X			V		Not country-specific. Marginally profitable, between 600-1200 $/ha income and 480 $/ha/yr net return, based on 1 $/day.
(Wiesenhütter 2003)	2003	X				V	Cape Verde, fences/smallholders, arid/semi-arid. Unprofitable and unfeasible without subsidies.
(Francis et al. 2005)	2005		X	V			India. CBA; NPV of 850 $, IRR 22% (IRR of 16% for processing) 0.40 $/l cost price of biodiesel (large scale).
(Kempf 2007)	2007	X	X		V		Tanzania. No full cost breakdown or CBA, only key cost factors provided. E.g. running cost between 115,000-200,000 TZS/ha. Only modest benefits and only side-profit generating complementary crop for rural poor.
(Peters and Thielmann 2007)	2007	-	-		V		Not country specific, costs observed at small-scale but unclear whether smallholders or plantation setting. No cost breakdown provided, total production cost estimated at 1.4-2.4 $/l. Opportunities for jatropha, but proper policy required.
(Tomomatsu and Swallow 2007)	2007	X			V		Kenya. No CBA, low profitability for smallholders (150-180 $/acre, rainfed) unless decentralised oil production. Improvement of local livelihood but unattractive as plantation crop.
(Messemaker 2008)	2008	X	X		V		Tanzania. Cost breakdown for steps in value chain provided; positive gross margin for nursing, collection, oil extraction and soap production but negative for large scale farming and biodiesel production. Also small scale farming and gathering negative unless seed price is increased from 100 to 300 TZS/kg.
(Loos 2008)	2008	X			V		Tanzania, semi-arid areas. CBA; only profitable if yields are >2 tons/ha/y, IRR of 65% if yield is 5.2 tons/ha and 0 if yield is 1.5 tons/ha/y.
(Amigun et al.	2008	-	-		V		Not country-specific, no cultivation but

2008)							biodiesel processing costs. Production of biofuels is not feasible at the moment unless yields or fossil prices increase (recom. to process locally) (not specifically jatropha).
(Muok and Källbäck 2008)	2008	X	X		V		Kenya, feasibility review. Tax policy plays a key role (no calculations).
(Econergy International Corporation 2008)	2008	-	-	V			Mozambique. No CBA, moderate average cost of 278 $/ton (feedstock costs), based on literature, not specified whether smallholders or plantation.
(Struijs 2008)	2008	X	X	V	V		Tanzania. 13-40 $/ha/yr profit, a small additional income for smallholders of 0.5-5.5 % / yr.
(Altenburg et al. 2009)	2009	-	-		V		India, business model not specified. Without subsidies and current yields only profitable for niche markets such as CDM-projects etc.
(ENERGIA 2009)	2009	X		V			SSA+A. Small scale-projects, all subsidised but generating additional income for local communities. No clear CBA, cost calculation for jatropha expelling shows profit.
(Moraa et al. 2009)	2009	X				V	Kenya. Jatropha is less profitable than orange and maize (smallholders).
(GTZ 2009b)	2009	X	X		V	V	Kenya. Only fences are financially feasible, plantation negative.
(Basili and Fontini 2009)	2009		X	V			Kenya, plantation of 80 ha, yield is 4 t/ha/yr. CBA; positive NPVs but also extremely volatile.
(Ariza-Montobbio 2009)	2009	X	X			V	India, 46 famers and 10 plantations. Low yields, 15,000 Rs/ha cost, none of the farmers reported profits. Max revenue is 2,500 Rs but loss of income at majority.
(Nielsen and de Jongh 2009)	2009	X		V			Mozambique. Prices of seeds to farmer are important, not much jatropha oil produced but indications are that it is economically viable.
(Mulugetta 2009)	2009	-	-	V			SSA, no data on production setting. Data is derived from Europe and USA, not based on existing projects.
(Estrin 2009)	2009	X	X		V	V	India, Karnataka. CBA; negative result under current conditions, government subsidies could make it profitable.
(Wahl et al. 2009)	2009	X			V		Tanzania. CBA; negative if yield is 2 ton/ha/yr, slightly positive if yield is 3 ton/ha/yr. Fences are recommended.
(Ariza-Montobbio and Lele 2010)	2010		X			V	India. Cultivation is unviable, only if yield increases to above 2.5 ton/ha/yr.
(Wiskerke et al. 2010)	2010	X			V		Tanzania. Jatropha oil feasible as diesel substitute not as woodfuel substitute, CBA performed, NPV from -1,500-+4,000 $.
(Van Zyl and Barbour 2010)	2010	X	X		V	V	Namibia. Based on secondary sources. Profits are marginal at best for smallholders.
(Habib-Mintz 2010)	2010		X		V		Tanzania. Based on company documents, business plans, no actual data. Company says able to produce jatropha oil for 0.18 $/l. More

							developments in the sector necessary (esp. political).
(Axelsson and Franzén 2010)	2010	X				V	India. Not profitable, high rate of discontinuation 85% (smallholders) based on qualitative data from interviews.
(Hawkings and Chen 2011)	2010		X	V			Global. IRR 15-18% (no details). Current production costs 900 $ PPO/ton (5 ton ha yr) but can in future be around 500 $ (7 ton ha yr).
(Feto 2011)	2011	X	X		V	V	Ethiopia. CBA; NPV and BCR positive but IRR<market value: large scale plantation not feasible, fence is feasible, oil extraction plant hardly viable, transesterification unviable.
(Wang et al. 2011)	2011		X			V	China. CBA; financially unfeasible (NPV -1.37 to -1.38), but positive environmental and energy performance.
(Silitonga et al. 2011)	2011	-	-	V			Indonesia. No CBA, only cost factors provided. Great returns but jatropha biodiesel more expensive than fossil, yield should be increased.
(Schoneveld et al. 2011)	2011	X	X			V	Ghana. Other crops have higher returns (Ghana). Waged employment increased, 67% of employees says life improved but not due to income (rather stability of income), value of displaced activity seems to be higher than returns.
(de Jongh and Nielsen 2011)	2011	X			V		Mz, Honduras, Mali. PPO chain is viable in Mozambique but not in Honduras. In Mali marginally viable. Yield around 500 kg/ha/yr. 0.05-0.10 $ paid for seeds. 0.77€ PPO, 1.13€ cost price biodiesel Honduras 0.83 € for PPO in Moz.
(Portale 2012)	2012	X		V			Tanzania. From year 2 onwards farmers have positive earnings, about 400 $ yr (yield 1.9 ton/ha/yr).
(Bouffaron et al. 2012)	2012	X			V		Mali. Case study to run economic model, result: on threshold of competitiveness, high sensitivity towards yields, fossil prices, labour costs and local conditions. NPV 370 for agronomy and 1370 for processing (yield 4.8 ton/ha/yr)
(Van Eijck et al. 2012)	2012	X			V		East Africa. Marginally profitable, only viable with low opportunity costs for labour, CBA included.
(Van Eijck et al. 2013)	2013	X	X		V		Tanzania. Marginally profitable, results of CBA of smallholder (8-18 M$/ha) and plantation model (-3-15 M$/ha) are quite similar.

sm= study is based on smallholders

pl= study is based on plantations

Positive: financial profit

Neutral: no clear financial gain

Negative: financial loss

Environmental aspects

Table 5A-6: Comparison of 38 studies that include jatropha biofuel LCAs and energy analysis (J=jatropha).

Study	Description	Functional unit	Value [kg CO_2-eq] or[%]	+* or -	Main conclusion and inclusion or exclusion of Land Use Change (LUC)
(Reinhardt et al. 2007)	LCA of jatropha biodiesel in India	1 ha of J	-131[a] (GHG)	+-	Lower GHG emissions from jatropha biodiesel than fossil diesel, however jatropha biodiesel performs worse on acidification, eutrophication and nitrous oxide. LUC for scarce vegetation included, not leading to changes in carbon stock.
(Achten et al. 2007)	Review	1 ha of J	2.25 ton[b]	+	Positive GHG balance, but dependent on type of land use converted to jatropha, cultivation intensity and distance to markets.
(Sampattagul et al. 2007)	LCA of jatropha biodiesel in Thailand	1 l J biodiesel	5.80E-03 Pt.[c]	+-	Major impacts, i.e. acute water eco-toxicity, chronic water eco-toxicity, and acidification are higher for jatropha Biodiesel than fossil diesel. Ozone depletion, human toxicity and global warming effects are more favourable for jatropha biodiesel. No LUC included.
(Achten et al. 2008)	Literature review [d]	various	various	+	Life cycle energy balance generally positive, as long as no ecosystems are degraded and by-products are used efficiently (transesterification is important contributor). LUC in discussion section.
(Croezen 2008)	LCA of jatropha produced in Tanzania and used in a power plant in the Netherlands	1 MJ electricity produced in CHP	62-77% GHG emission reduction	+	Depending on useful application of original vegetation, no LUC included.
(Muok and Källbäck 2008)	Feasibility of jatropha in Kenya, from literature	CO_2 sequestration/ yr/tree or ha	8 kg CO_2 (or 20 tons CO_2 seq. /yr/ha)	+	There is potential for a biofuel sector in Kenya. No calculations included.
(Whitaker and Heath 2008)	LCA of using jatropha oil in Indian locomotives (blended with fossil diesel)	1000 km by train and car B5-B100	3-62% GHG reduction	+	Even a blend with 5% jatropha biofuel has positive effect on GHG balance. No LUC included, cultivation on wastelands assumed.
(Prueksakorn and Gheewala 2008)	Energy analysis of jatropha in Thailand	Net energy gain (NEG) and net energy ratio (NER)	4720 GJ/ha NEG 6.03 NER	+	Even without considering byproducts still >1 NER. Main contributors: cultivation, transesterification and transport. No LUC included.
(Dehue and Hettinga 2008)	Production jatropha in India for energy use in UK (based on data from D1 Oils in India) compared with fossil diesel	1 ton biodiesel produced	934-1983 kg CO_2 e/ton, a 66 to 71% reduction	+	Jatropha has a better GHG performance than palm oil biodiesel, scenario with LUC (66-68%) and without LUC (70-71 %) (EC and RTFO methodology) (4.5 ton/ha seed yield).

	and palm oil				
(Struijs 2008)	jatropha in Tanzania for energy production in the Netherlands	1 kWh of energy produced compared with fossil diesel	60-300 % GHG savings	+	Both plantation and smallholders. Depending on use of by-products and CO_2 sequestration. Plantation assumed on degraded savannah vegetation, therefore no LUC, smallholder cultivation assumed in addition to current land use.
(Ndong et al. 2009)	LCA jatropha in West Africa, field study	1 MJ of JME compared with fossil diesel	72% GHG savings (23.5 g CO_2 eq per MJ jatropha biodiesel, fossil energy ratio: 4.7	+	The performance is better than other first generation biofuels. LUC included in discussion section; cultivation on former cotton estate so C-stock is improved.
(Lam et al. 2009)	Comparison Palm Oil and jatropha for biodiesel production Malaysia	1 ton biodiesel produced Land area requirement Energy ratio	118% more land than for palm. The energy ratio is 2.27 for oil palm and 1.92 for jatropha. CO_2 sequestration is 20 times higher for oil palm	+-	Exact data used for land use change are not reported. It seems that the jatropha case is based on literature while for Oil Palm local data is available.
(Basili and Fontini 2009)	Environmental sustainability in Kenya, review	1000 MJ jatropha biodiesel	56.7 kg CO2-eq.	+	Only secondary data was used (Tobin and Fulford 2005 and Prueksakorn and Gheewala 2006). LUC only discussed; jatropha plantation can store 5.5-20 tC/ha/yr if marginal land is used there is no issue.
(Nallathambi Gunaseelan 2009)	Comparison of energy flows (1) biodiesel + CH_4 production and (2) only CH_4 production	J production on 1 ha rain fed dry land	energy yield: 72 GJ/ha/yr and 79 GJ/ha/yr resp.	+	All components of the plant are capable of conversion by anaerobic digestion. CH_4 production only, is more efficient than +biodiesel. LUC; assumed to be cultivated on wasteland, therefore no LUC.
(Ou et al. 2009)	Comparison 6 biofuels pathways on LCA in China compared with fossil fuel	1 MJ energy produced	51.971 g CO_2-eq. 49% reduction of GHG emissions	+	Jatropha biofuel scores best on GHG and energy reduction, together with cassava-derived ethanol and biodiesel from used cooking oil. (no pesticides assumed, yield 5 tons/ha). No LUC.
(Veen and Carrilo 2009)	Comparison of Palm Oil and jatropha for biodiesel in Peru	1 l biodiesel, use: 1 km	-0.01-0.84 kg Co_2-eq./km	+	oil palm is the favourable source for biodiesel production over jatropha. LUC included, if jatropha planted on degraded forest or degraded land the GHG balance is positive, if planted on primary or secondary forest the balance is negative.
(Kirkinen et al. 2009)	2 methods of GHG calculations comparing jatropha biodiesel in India with fossil and forest residue Fischer-Tropsch with fossil	energy produced	33 % GHG emission reduction	+	Jatropha biodiesel has about 33% less emissions than fossil diesel, FT as well irrespective of method.
(Estrin 2009)	GHG for different scenarios in India	1 tonne biodiesel produced	0.26-0.47 energy ratio	+	Especially rainfed scenarios perform better than irrigated scenarios on GHG emissions. No

					LUC included, but if cultivation is assumed on grassland and abandoned crop land, the effect is small (3-18 % increase of total CO_2-farming emissions/ha).
(Hooijkaas 2010)	LCA of jatropha oil from company in Tanzania,(used in Van Eijck accepted)	jatropha oil processed in Europe used in CHP	-47-128 % GHG emission reduction	+-	Huge range due to land use change.
(Gmünder et al. 2010)	Electrification Indian village jatropha oil in generator	1 kWh electricity generated	0.27 kg CO2-eq./ kWh and 0.088 Eco-indicator 99 points. A reduction of GHG emissions by a factor 7 compared to grid or diesel generator	+-	Low GHG emissions but other environmental impacts are higher, eg summer smog (due to CO released in boiler. A PV system outperforms jatropha. The process chain is a larger contributor of GHG emissions than the cultivation stage. No LUC included.
(Arvidsson et al. 2010)	Comparing vegetable oil from rape, oil palm and jatropha	1 kWh by heavy duty truck	GWP: 600 g CO_2-eq/kWh_{engine} for jatropha	+-	Oil palm with co-production of biogas is the option with the lowest environmental impacts. High acidification for jatropha, due to diesel use for irrigation. No LUC included.
(Prueksakorn et al. 2010)	Jatropha plantation in Thailand, 2 cases perennial and yearly	1 ha of jatropha plantation	The net energy ratio (output / input energy) is 6 for the perennial plantation and 7,5 for the annual plantation. Net energy balance of perennial is 4720 GJ and yearly 9860 GJ.	+	The yearly plantation (biomass is used) performs better than the perennial plantation (seeds are used). It is uncertain if this is practised in reality. No LUC included.
(Bailis and Baka 2010)	GHG emissions, jatropha based Jet Fuel from Brazil	1 GJ biodiesel produced	40 kg CO_2-eq. per GJ of fuel, 55% reduction	+	However, range can be as high as 13-141 kg CO_2-eq. /GJ or -85% to +60% compared to reference scenario depending on type of land. (direct) LUC included.
(Romijn 2010)	Carbon debt in Southern Tanzania by large scale plantation	1 kWh of energy produced versus fossil reference (following Struis, 2008)	-26 to + 24.5 tC/ha/yr total GHG emissions 33 year carbon debt on Miombo woodland	+-	Jatropha can sequester carbon if grown on severely degraded conditions, but on tropical woodlands it will induce emissions, LUC included.
(Whitaker and Heath 2010)	LCA jatropha biodiesel(blends) in India (rail+road sector) compared to fossil diesel	1000 t of goods or passengers hauled over 1 km by rail or road	14% reduction of life cycle emissions 17 % reduction of petroleum consumption.	+	Rail sector for near future, road freight eventually largest benefits due to intense use (more than road passenger). No LUC included.
(Feto 2011)	GHG in Ethiopia	1 kg dry jatropha seeds and MJ input per MJ jatropha biodiesel	262 % energy savings compared to diesel -0.36 kg CO_2-eq. of net carbon increase for fence	+	Cultivation as a fence leads to higher GHG savings as from a plantation. The transesterification stage is the highest CO_2 emitter. LUC: if bushland is converted to a plantation, a reduction in soil carbon of 0.89 kg CO_2-eq. occurs.

(Wang et al. 2011)	LCA in China	Heat value unit litre biofuel produced (jatropha oil+ biodiesel)	7.34-8.04 kg CO_2-eq. reduction, energy balance 1.47-1.57	+	Financially unfeasible, but environmentally positive. Yield, by-products and farm energy inputs are main factors. No LUC included.
(Bailis and McCarthy 2011)	Carbon impacts of dLuc in Brazil and India	Carbon stock per ha	3-10 tons C/ha	+-	No detectable change in carbon stocks where woodlands were replaced, but large losses when native woodlands were replaced. No GHG analysis included.
(Almeida et al. 2011) (+2009)	Generic LCA compared to fossil diesel	MJ biodiesel produced	Reduction of 51%, 8 times less energy consumption	+	Impact on ozone is lower, but eutrophication and acidification is 8 times higher. No LUC included.
(Skutsch et al. 2011)	Environmental impacts in Mexico	Carbon stock per ha	1.14 kg carbon 2-14 years of payback period	+-	In some cases carbon losses are very high and may never be recovered. No GHG analysis.
(Chum et al. 2011) (IPCC 2012)	Plant oils in general	1 MJ fuel	-20-60 g CO_2-eq./MJ	+-	Based on secondary sources (Whitaker and Heath, 2010 and (Hoefnagels et al. 2010) amongst others,). Fig 9.9 (no LUC included) and 9.10 (dLUC included)
(de Jongh and Nielsen 2011)	Impacts in Honduras, Mali and Mozambique	Carbon stock per ha	-	+	If primary forest is cleared, carbon debt is 1,900 years, however no clearing observed.
(Paz and Vissers 2011)	LCA of jatropha plantation in Mozambique	1 MJ biodiesel produced	38 to 48% GHG emission reduction	+	Biodiesel either produced in Mozambique or UK. No LUC, cultivation assumed on former tobacco estate therefore neutral LUC impact. (if different land uses are included the range is -1150 to +400 % emission reduction)
(Pandey et al. 2011)	LCA of small scale high input jatropha in India	1 ha	1.77 net energy ratio, 20 Mt CO_2 emissions/ha/5 yr	+	Data is from literature and test plot in India, however, yield seems high. No LUC included.
(Firdaus and Husni 2012)	Comparison of carbon emissions at wasteland and converted to jatropha plantation in malaysia	1 ha	No effect, only 1.5 years before jatropha can offset effect	+	Converting wasteland to jatropha showed no adverse effects. (LUC is calculated, no full LCA analysis).
(Van Eijck et al. 2013)	Analysis of plantation and smallholders system	MJ energy produced.	-85 to 278 % GHG emission reduction.	+-	Processing in Tanzania or Netherlands. Depending on yield, carbon stock calculated by satellite analysis. LUC included.
(Hellings et al. 2012)	Carbon storage in jatropha trees in Northern Tanzania	Carbon stock per tree	11.86 kg CO_2/tree or 20-30 t CO_2/ha		Values obtained by destructive sampling. No full LCA included.
(Franke et al. 2012)	LCA for 6 different settings (both smallholders and plantation) in two timeframes (India, Mali, Tanzania)	1 MJ, 1 ha or % reduction relative to fossil	Average 491 g CO_2-eq / MJ FAME. Range: 387-1311 kg CO_2-eq /ha 51-74 % reduction	+	Sugarcane and palm oil based biofuels perform better than jatropha. Important variables are yield, previous land cover and use of by-products. No (i)LUC effects included (the calculator does include this as an option).

[*]: Estimated GHG emission reduction, which is positive (+), or increase which is negative (-).

[a]: This is a combination of six jatropha biofuels pathways.

[b]: 2.25 ton CO_2 sequestration ha^{-1} yr^{-1} in the standing biomass, cited from (Francis et al. 2005).

[c]: This is the value for the total environmental impact of the three stages of production.
[d]: Based on (Tobin and Fulford 2005) and (Prueksakorn and Gheewala 2006).

Note: Almeida 2009 was published in Almeida 2011 and has therefore not been analysed separately; Kirkinen 2010 was subsumed under Kirkinen et al. (2009), which reported the same results. Some studies that included a literature review of LCA studies have not been taken into account in this table because their conclusions were based on other sources. However, they have been taken into account in the text of this assessment. These studies are (Silitonga et al. 2011), (Axelsson and Franzén 2010) and (Ravindranath et al. 2011).

Table 5A-7: Studies that included biodiversity, their general conclusion and the country of study

Study	Positive (increase)	Neutral*	Negative (loss)	Country of study
(Spaan et al. 2004)	V			Mali and Burkina Faso[a]
(Mwamila et al. 2009)			V	Tanzania[b]
(Finco and Doppler 2010)			V	Northern Brazil[c]
(Van Zyl and Barbour 2010)		V		North Eastern Namibia[d]
(Schut et al. 2010b)		V		Mozambique[e]
(Broadhurst 2011)		V		Tanzania[f]
(Ravindranath et al. 2011)	V	V		India[g]
(Skutsch et al. 2011)		V	V	Mexico[h]
(Van Eijck et al. 2013)		V	V	Tanzania[gi]

[*]: neutral means no clear conclusion or no impact actually measured.
[a]: Contour vegetation barriers are described, planted with jatropha; these can preserve indigenous woodland and bush-land.
[b]: Biodiversity impact is described at two locations in Tanzania; however, no actual impact is assessed but only possible impacts are listed, such as habitat fragmentation, disturbance of migration routes, invasiveness of jatropha and the risk of destroying mangroves due to chemicals in the water. In addition, areas have been identified that are rich in wildlife and where plantations are being planned. The total wildlife population may be affected if breeding sites of the wildlife are disturbed.
[c]: Families interviewed in Brazil deforested on average 0.72 h for jatropha production.
[d]: There is a high risk of loss of biodiversity in the Kavango and especially Caprivi Region, two high-value biodiversity areas for large scale jatropha production. Site-specific Environmental Impact Assessments are required.
[e]: Some smallholder jatropha projects in Mozambique are situated in National Parks; this may be a potential risk; there is the possible impact of jatropha as an invasive species and the lack of agro-ecological knowledge of smallholders.
[f]: Cultivation in a plantation system has a greater potential impact, but no actual measurements were performed.
[g]: Policy in India prevents the conversion of forests, which have stabilised since 1990. Biofuel development is targeted at marginal lands which could lead to biodiversity conservation or improvement.
[h]: As regards the smallholders in Mexico, some deforestation has occurred but not significantly so.
[i]: Loss of biodiversity is a risk on large-scale plantations if they are located in an area with rich biodiversity; however, if cultivation is performed in a fence system and a suitable location has been chosen, there is hardly any influence.

Table 5A-8 : Studies that included food security impact, their main conclusions, the country of study and the source of the data

Study	Pos-itive	No effect	Neg-ative	Country of study, source of data, the way in which food security is assessed and the main conclusion
(Ethnic Community Development Forum 2008)			V	Myanmar, 131 interviews. Forced growth of jatropha caused direct competition on good land, lower time availability for food crops and food crops had to be grown further away, decreasing production.
(Mitchell 2008a)		V		Tanzania, 74 interviews with jatropha farmers and observations. Risks were identified, but for smallholders impact is considered to be minimal since they still cultivate food crops. The labour demand for weeding in the first years could conflict with labour demand for food crops.
(Loos 2008)		V		Tanzania, 248 households interviews. No difference between jatropha smallholders and control group, jatropha seems to be planted in addition to food, not replacing it. The project is located in a food-insecure area, this seems to have the largest influence on food security.
(Gordon-Maclean et al. 2008)	V	V	V	Tanzania, 1.5 months study, interviews with key stakeholders and company case studies; smallholders and plantation. Positive (if agricultural knowledge is increased, new additional source of income) or negative effects (if food crops are replaced) are possible.
(Altenburg et al. 2009)		V		India, 13 case studies. Food crops have higher returns than jatropha therefore no large food competition. Food security not threatened by government centred plantations. On farmer centred plantations the impact is not yet foreseeable, displacement of landless farmers can be an issue in corporate centred models.
(Mwamila et al. 2009)			V	Tanzania, survey based on questionnaires, focused on large scale biofuel production. Possible risks include food crop replacement and lower food production due to reduced household food plot labour.
(Puente-Rodríguez 2009)		V		Honduras, 8 month fieldwork and literature study, 60 interviews and observations, focus on smallholders. Jatropha is planted as fences therefore no food crop replacement.
(Peters 2009)		V	V	Mozambique, 84 household surveys in 3 villages, plantations. The employees had a significantly bettersocio- economic situation, increased income and increase expenditure on food. However household food production decreased, this had no short term effect. Long term impact will depend on food availability.
(Practical Action Consulting 2009)	V	V		3 continents, 15 case studies, all smallholders. In Thailand organic fertiliser on food crops from jatropha seedcake made higher yields possible and increased food security. Similar positive impacts or no impacts at other sites.
(Ribeiro and Matavel 2009)			V	Mozambique, based on 50 interviews, 27 questionnaires and observations at 7 plantations. Negative impact because jatropha replaced food crops due to limiting resources (land) for subsistence farmers.
(Ariza-Montobbio 2009)			V	India, data from 49 plots. Food crops were displaced by jatropha, also crop diversification decreased due to jatropha, impact is higher for smaller farmers compared to larger ones.
(Finco and Doppler 2010)			V	Brazil, survey of 27 jatropha farmers. Food crop area was converted into jatropha therefore decrease in food production resulted.
(FAO 2010a)		V		Tanzania, country data. All four dimensions analysed, no effect found. Small increase in yields can offset any effect caused by biofuel plantations.
(Moers 2010)	V			Honduras, smallholder project in Gota Verde running for 3 years. Improvement because of mechanised equipment and access to credit. Jatropha biofuel provided energy security (other farmers did not have diesel needed for land preparation). Expected jatropha harvest could serve as guarantee for loan.
(Axelsson and Franzén			V	India, 106 interviews, jatropha was planted on crop lands and

2010)				therefore substituted food crops (perhaps due to too high expectations).
(Chachage and Baha 2010)			V	Tanzania, 100 interviews and case study on plantation company. Employees did not tend their food crop plots anymore, therefore food production declined.
(Arndt et al. 2011)	V		V	Mozambique, CGE modelling using scenarios with jatropha production. GDP is increased which reduces poverty and increases food security, but using female labour intensively for jatropha cultivation can have a negative effect.
(Broadhurst 2011)		V	V	Tanzania, case studies at plantation and smallholders and literature review. Plantation has possible negative effect due to the employment of local subsistence farmers as wage labour, and the lower domestic food production that may result. For smallholder jatropha growers no negative effect is expected, they prioritise food production especially if jatropha is planted as a fence.
(Skutsch et al. 2011)		V		Mexico, 72 interviews with jatropha smallholders and non-jatropha smallholders. Food production was maintained.
(Schoneveld et al. 2011)	V		(V)	Ghana, 60+ interviews and group discussions. 6.5 % of respondents reported a net food production reduction, but on average 29% and 5% increase in food crop area in two districts due to opening of new cropland. 54% of respondents reported increased food security.
(de Jongh and Nielsen 2011)	V	V		Mozambique, Honduras (see also Moers 2010) and Mali, evaluation of 3 projects that were running for 3 years. No food displacement (all jatropha planted as fences), sometimes increased income.
(German et al. 2011b)	V			Zambia, interviews with 30 households, smallholders. Average food increase of 5-29% found. Some decreased food production due to displacement.
(Portale 2012)	V			Tanzania, 102 interviews. Higher perceived food security by jatropha outgrowers.
(Van Eijck et al. 2013)		V		Tanzania, interviews, observations and measurements (incl. statistics), smallholders and plantation. Negative effects are possible but measures can offset them. Meals are provided to employees.

Note: Ewing and Msangi (2009) do not focus on jatropha in their methodology paper; therefore, this study has not been taken into account in this table. (Mshandete 2011) is a review paper and has therefore also not been taken into account.

Table 5A-9: Studies that deal with aspects of local prosperity, their main findings, country of study and the source of the data.

Studies	Sm*	Pl*	Positive	Neu-tral	Nega-tive	Country of study, source of data, main conclusion
(Brew-Hammond and Crole-Rees 2004)			V			Mali, interviews and analysis. A multi-functional platform has positive effects due to increased energy access.
(Benge 2006)	X		V	V		Not country specific, literature. Increased energy access is positive, market uncertainties and economic feasibility are challenging.
(Wani et al. 2006)		X	V			India, literature review. Can increase income (carbon credit earnings) and generates employment.
(Tigere et al. 2006)	X		V			Zimbabwe, interviews with 60 jatropha farmers. Income generating possibilities.
(Wijgerse 2007)	X		V	V		Tanzania, 2 months field study including observations and interviews. Electricity access is beneficial, jatropha-generated electricity could be financially viable with system adaptations, and provided the project is managed well and local

						stakeholders are adequately involved.
(de Jager 2007)	X		V			East Africa, data from farmers. Rural livelihoods can be improved when smallholders (in groups) successfully engage in commercial activities and increase their knowledge (not specifically for jatropha).
(Tomomatsu and Swallow 2007)	X		V	V		Kenya, observations, interviews and literature. Profitability for smallholders is minimal unless oil extraction is decentralised
(Wijgerse 2008)	X		V			Mali, observations and interviews. Some technical challenges for electricity systems can be overcome. Jatropha is cheaper than diesel and creates extra income for farmers.
(Mitchell 2008a)	X		V			Tanzania, 74 interviews. Increased income, but distribution not always equal.
(Loos 2008)	X				V	Tanzania, 284 interviews. Too early to assess, in the short term the effects are negative.
(Laltaika 2008)	X	X			V	Tanzania, opinion paper. Traditional lifestyle of pastoralists clashes with objectives of large-scale jatropha farming.
(Rajagopal 2008)		X			V	India, literature review. Jatropha cultivation can worsen access to fuelwood and fodder by landless poor.
(ProForestLtd. 2008)	X		V	V		India, SSA, literature review, questionnaires. Job creation and income generation can be achieved, but possibly changes in lifestyle.
(Ewing and Msangi 2009)			V			Developing countries, literature. Can increase welfare, productivity and health.
(Altenburg et al. 2009)	X		V			India, 13 case studies. Varies with type of value chain.
(GTZ 2009b)	X			V	V	Kenya, interviews with 289 jatropha farmers. No farmer at break-even yet.
(Peters 2009)		X	V		V	Mozambique, survey of 84 households in 3 villages and observations. Employees experienced increase in income, increase in expenditures and decrease in leisure time.
(Arndt et al. 2009)			V			Mozambique, CGE-modelling. Enhances growth and poverty reduction.
(Practical Action Consulting 2009)			V			8 case studies in different countries. Overall increased employment and energy access.
(Van Eijck 2009)	X		V			Tanzania, field data 3 yr observations at smallholders (hedge and small plantations) and processing company. Modestly increased income and skills.
(Mujeyi 2009)	X		V			Zimbabwe, 120 interviews (43 jatropha). Benefits from selling and reduced consumption of fuels.
(Nygaard 2010)	X			V	V	Mali, review documents and observations. Multifunctional platform projects have many socio-organisational challenges.
(Ariza-Montobbio and Lele 2010)					V	India, 49 interviews and observations at 14 plantations. Impoverishes farmers, reduced access to fodder, more off farm activities due to uncertainty about jatropha profits.
(Gmünder et al. 2010)	X		V			India, fieldwork. Increased access to energy through decentralised power generation.

(Moers 2010)	X		V			Honduras, 3 yr project. Improvement of income, skills, local currency introduced.
(Habib-Mintz 2010)	X	X		V		Tanzania, fieldwork. Job creation but unclear if really accomplished.
(Schut et al. 2010a)				V		Mozambique, interviews. Majority of biofuel projects target areas with good infrastructure, policy required to target rural areas.
(Bos et al. 2010)				V		Mozambique, case study. Too early to observe impacts.
(Schut et al. 2010b)			V			Mozambique, interviews with various stakeholders, observations and business proposals. Creation of between 0.14-0.17 jobs per hectare estimated at jatropha projects, investments almost 3 M$, or almost 1,700 $/ha, mostly for EU market.
(Axelsson and Franzén 2010)					V	India, 106 interviews. 85% of farmers have discontinued, jatropha failed to provide income.
(Mponela et al. 2010)	X		V			Malawi, 129 interviews. Poor households are more likely to adopt jatropha, can provide income but needs regulations.
(Mshandete 2011)			V			Tanzania, literature. Can provide opportunities like employment, but regulations needed.
(Broadhurst 2011)	X	X	V			Tanzania, 3 case studies. Job creation and increased income. Smallholder model is preferred.
(Skutsch et al. 2011)	X		V			Mexico, 72 interviews. Increased employment opportunities for landless labourers.
(Schoneveld et al. 2011)		X	V			Ghana, interviews, plantation. 120 jobs created. Livelihood improved according to 67% of 31 respondents.
(de Jongh and Nielsen 2011)	X			V		Mozambique, Honduras, Mali, data from 3 yr running project. Currently low profitability but potential for improvement, energy access improved.
(Portale 2012)	X		V			Tanzania, 102 interviews. 16 indicators identified, economic access perception index, subjective well being index and social capital index. All scores are higher for jatropha farmers than other farmers.
(Van Eijck et al. 2013)	X	X	V			Tanzania, interviews, observations and measurements. Positive impacts for smallholders and plantations but depending on local implementation.
(Prakash 2012)	X			V		6 countries, project documents and observations. In all projects, low prices and low production rates have prevented producers from benefiting.

*Sm=impact from or on smallholders; pl=impact from or on plantation

Table 5A-10: Studies that cover aspects of labour and working conditions, their main findings, country of study and the source of the data

Study	Sm*	Pl*	Pos.	Neutral - no effect	Negative	Country of study, source of data and main conclusions
(Ethnic Community Development Forum 2008)	X				V	Myanmar,131 interviews. Forced labour occurred.
(Gordon-Maclean et al. 2008)			V			Tanzania, interviews and observations. Additional benefits were provided.
(GTZ 2009b)	X			V		Kenya, interviews with 289 jatropha farmers. No farmer at break-even yet.
(Peters 2009)		X	V			Mozambique, household survey (84) in 3 villages and observations. Number of absent days higher at one plantation, therefore unclear if employees would stay at the plantation if there would be other job opportunities (wages too low to cover opportunity costs).
(Van Eijck 2009)	X		V			Tanzania, based on field data, 3 yr observations at smallholders and processing company. Many additional benefits provided by processor for its worker, such as lunch, health care etc.
(Ribeiro and Matavel 2009)		X			V	Mozambique, interviews (50) and observations at 7 plantations. 500 jobs created.
(Nielsen and de Jongh 2009)	X			V		Mozambique, based on field data from a 3 yr old project. Labour demand for jatropha coincides with labour demand for food.
(Ariza-Montobbio and Lele 2010)	X				V	India, 49 interviews and observations at 14 plantations. Uncertainty about trade offs.
(Schut et al. 2010b)	X	X	V			Mozambique, interviews and observations. One contract voided, difference between permanent and casual labour. Lack of locally available skilled labour.
(Chachage and Baha 2010)		X			V	Tanzania, 100 interviews, anecdotal evidence.
(Van Eijck et al. 2013)	X	X	V			Tanzania, interviews, observations and measurements. Many additional benefits provided, no irregularities observed.

*Sm=impact from or on smallholders; Pl=impact from or on plantation

Table 5A-11: Studies that analysed land ownership and land rights aspects, their general conclusions, country of study and source of the data

Study	Sm*	Pl*	Pos.	Neutral - no effect	Neg-ative	Country of study, source of data, main conclusions
(Weyerhaeuser et al. 2007)		X		?		China, literature. Rural land management in China is highly complex. Villages often own small areas of land (<300ha).
(Ethnic Community Development Forum 2008)					V	Myanmar, 131 interviews. Land confiscation occurred.
(Mitchell 2008a)	X			V	V	Tanzania, 74 interviews and observations. Key expansion constraints for jatropha cultivation are identified (lack of labour andland); due to high land pressure, farmers who adopt jatropha have to choose between hedgerows, intensifying cultivation, or displacing another crop.
(Laltaika 2008)					V	Tanzania, opinion paper. Jatropha changes traditional

						pastoralist lifestyle.
(ProForestLtd. 2008)		X			V	SSA and Asia, literature review and survey of experts. Increased land conflicts are likely.
(Gordon-Maclean et al. 2008)	X	X			V	Tanzania, interviews (key stakeholders) and observations, company case studies. Compensation payment processes are often very unclear.
(GRAIN 2008)		X			V	India, secondary sources. Marginalisation threats arise from plantations often being located in impoverished areas where people do not protest.
(Altenburg et al. 2009)		X		V		India, 13 case studies. Potential to rehabilitate degraded lands, but good negotiations with local populations are necessary.
(Mwamila et al. 2009)		X			V	Tanzania, questionnaires. Unclear and confusing land acquisition process.
(Ribeiro and Matavel 2009)	X	X			V	Mozambique, 50 interviews, 27 questionnaires and observations at 7 plantations. Promises were not kept.
(Salfrais 2010)	X		V	V		Mali, smallholders, based on 66 interviews. No effect on land access, could possibly be worse in future if pressure on land increases (see also section on gender). Some border conflicts were solved.
(FAO 2010a)	X				V	Tanzania, country data, company case study. Unclear compensation process, although company followed the law.
(Habib-Mintz 2010)		X			V	Tanzania, fieldwork in 2 districts. Unclear compensation process, difficult to assess 'fair' compensation.
(Schut et al. 2010a)				V		Mozambique, 50 interviews, 10 field visits. Investors prefer land in areas with good infrastructure, skilled labour, access to goods and services and storage and processing facilities, regulatory policy is needed.
(Schut et al. 2010b)		X		V		Mozambique, interviews and observations. Investors have so far requested 3.5% of available land; land is preferred in regions with good infrastructure etc. (same as previous entry).
(Chachage and Baha 2010)		X		V	V	Tanzania, 100 interviews and case study on company. Confusion and disputes over compensation, communities satisfied until project discontinued. Land has not reverted back to original owners.
(Andrew and Van Vlaenderen 2010)		X		V		Mozambique, ESIA[a] including various interviews at a jatropha company. Measures can prevent resettlements.
(Skutsch et al. 2011)	X	X		V		Mexico, smallholders, 72 interviews. No cases of land alienation encountered.
(Schoneveld et al. 2011)		X			V	Ghana, 30+ interviews, satellite images. Large areas deforested which leads to communities losing access to resources.
(Van Eijck et al. 2013)	X	X		V	V	Tanzania, interviews, observations and measurements. Higher risk of difficult consequences for communities at plantation systems that are discontinued than in smallholder systems, but measures can be taken to mitigate plantations effects.

*Sm=impact from or on smallholders; Pl=impact from or on plantation

[a] Environmental and Social Impacts Assessments (ESIA)

Note: Wani et al. (2006), Estrin (2009), Brittaine and Lutaladio (2010) and Wahl et al. (2009) mention minor relevant aspects only, and are hence excluded from the table. Mshandete (2011) lists concerns and expected impacts but does not contain observed impacts; therefore, this study is not included in the table.

Table 5A-12: Studies that include gender aspects and their main conclusions, country of study and source of the data

Study	Pos.	Neutral - no effect	Nega tive	Country of study, source of data, main conclusions
(Brew-Hammond and Crole-Rees 2004)	V			Mali, based on interviews and analysis. Multifunctional platform saves time and increases income for women, girls education increased.
(Mota 2009)			V	Mozambique, based on interviews, survey and observation (plantation). Women who worked at the plantation reduced their time spent on farm activities, compensation unclear.
(ENERGIA 2009)	V			SSA+Asia, based on interviews at 8 case study locations (smallholders). Empowerment through energy access.
(Peters 2009)			V	Mozambique, based on household survey (84) in 3 villages and observations (plantation). Especially women work on household food plots and have domestic tasks, when employed by the plantation company their time for these tasks reduces or leisure time reduces.
(Nygaard 2010)		V		Mali, based on review documents and observations (multifunctional platform). In practice men assumed a role in the management of the platforms and 43% of the women groups discontinued.
(Salfrais 2010)		V		Mali, based on 66 interviews (smallholders). No effect on land access so far, but it could possibly be reduced in the future if pressure on land increases.
(Brittaine and Lutaladio 2010)		V		SSA, review of literature and interviews with consultants (smallholders). Pre-existing gender inequalities may be sustained.
(Arndt et al. 2011)		V		Mozambique, based on gendered CGE modelling (plantation and smallholders). Using intensive women's labour decreases food production but yield improvements can offset this effect.
(Skutsch et al. 2011)		V		Mexico, based on 72 interviews (smallholders). Jatropha farming is a men's job, dehulling a women's job.
(Portale 2012)		V		Tanzania, 102 interviews. Gender index shows no difference.
(Prakash 2012)		V		6 countries, project info. Women participation was so far low in the projects, but lot of scope; from soap production to technical female officers.

Note: (Tigere et al. 2006), (Mitchell 2008a) and (de Jongh and Nielsen 2011) offer a few gender observations but are not included in this table because they did not specifically analyse gender issues. Other studies with a gender analysis did not focus specifically on jatropha but on biofuels more generally. These are: (Clancy et al. 2004), (Rossi and Lambrou 2008) and (Verhoog 2010).

6 Analysis of socio-economic impacts of sustainable sugarcane-ethanol production by means of inter-regional Input-Output analysis: Demonstrated for Northeast Brazil

SARA HERRERAS MARTÍNEZ, JANSKE VAN EIJCK, MARCELO PEREIRA DA CUNHA, JOAQUIM J.M. GUILHOTO, ARNALDO WATER, and ANDRÉ FAAIJ

Renewable and Sustainable Energy Reviews 28 (2013) 290-316 [22]

Abstract

This study assesses the socio-economic impacts in terms of value added, imports and employment of sugarcane-derived bioethanol production in Northeast (NE) Brazil. An extended inter-regional Input-Output (IO) model has been developed and is used to analyse three scenarios, all projected for 2020: a business-as-usual scenario (BaU) which projects current practices, and two scenarios that consider more efficient agricultural practices and processing efficiency (scenario A) and in addition an expansion of the sector into new areas (scenario B). By 2020 in all scenarios, value added and imports increase compared to the current situation. The value added by the sugarcane-ethanol sector in the NE region is 2.8 billion US$ in the BaU scenario, almost 4 billion US$ in scenario A, and 9.4 billion US$ in scenario B. The imports in the region will grow with 4% (BaU scenario), 38% (scenario A) and 262% (scenario B). This study shows that the large reduction of employment (114,000 jobs) due to the replacement of manual harvesting by mechanical harvesting can be offset by additional production and indirect effects. The total employment in the region by 2020 grows with 10% in scenario A (around 12,500 jobs) and 126% in scenario B (around 160,000 jobs). The indirect effects of sugarcane production in the NE are large in the rest of Brazil due to the import of inputs from these regions. The use of an extended inter-regional IO model can quantify direct and indirect socio-economic effects at regional level and can provide insight in the linkages between regions. The application of the model to NE Brazil has demonstrated significant positive socio-economic impacts that can be achieved when developing and expanding the sugarcane-ethanol sector in the region under the conditions studied here, not only for the NE region itself but also for the economy of the rest of Brazil.

[22] This chapter is based on research funded by Solidaridad (supported by NL Agency) and Global-Bio-Pact (supported by the European Commission).

6.1 Introduction

Among first generation biofuels, sugarcane derived ethanol produced in Brazil is one of the most competitive fuels and is, together with corn based ethanol from the US, one of the two world leading sources of biofuel, covering 87% of global production (Crago et al. 2010; Lamers et al. 2011). The production of fuel ethanol has increased enormously over the last decade, from 340 PJ in 2000 to 1,540 PJ in 2009, and to over 1,780 PJ in 2011 (Lamers et al. 2011; BP 2012; Lamers et al. 2014). Sugarcane-ethanol also has a favourable GHG balance, compared to other crops such as sugar beet, wheat straw and corn (Goldemberg et al. 2008; Crago et al. 2010). Brazil is a large producer thanks to amongst other reasons, the supportive governmental policies (van den Wall Bake et al. 2009; Azadi et al. 2012). Brazil also has a favourable tropical climate with sufficient rainfall and high temperatures. Brazil produced 506 PJ ethanol in 2009, and around 540 PJ in 2011,which is about one third of the total global fuel ethanol production. The majority (>80%) is used within Brazil, export is limited and fluctuates with the price of sugar (Lamers et al. 2011; Lamers et al. 2014). The majority of sugarcane and ethanol production in Brazil, is located in the Centre-South (CS) of Brazil. In the Northeast (NE) of Brazil, on the other hand, mostly sugar is produced and only 7% of the total national ethanol production (Companhia Nacional de Abastecimento 2011).

In order to facilitate manual harvesting, sugarcane fields need to be set on fire to remove dry leaves and repel poisonous animals. There are numerous negative impacts associated with burning sugarcane such as soil degradation and increased air pollution. Therefore, a Brazilian regulation that came up in 2002 (11241/02), aimed to gradually eliminate this practice by limiting manual harvesting and replacing it with mechanized harvesting. Mechanized harvesting brings along a number of benefits such as soil improvement; leaves of the sugarcane are left on the ground, instead of being burned, acting as fertilizers and maintaining the humidity of the soil. Furthermore, it is more cost effective. On the other hand, mechanized harvesting negatively impacts employment, an estimated 114,000 sugarcane cutters are expected to lose their jobs in the CS region between 2006 and 2020 (BNDES and CGEE 2008b). Most of these workers are immigrants from the NE.

There are large differences between the production systems of sugarcane-ethanol of the CS and the NE regions. While the production in the CS is well developed and continuously improving in terms of efficiency and sustainability, the productivity achieved in the NE is lower due to climate, terrain characteristics and lower technological levels. Although the sector in the NE has some benefits compared to the sector in the CS such as good storage and loading infrastructure in the terminals, lower transport costs, higher incentives for sugar exports, there is still room for improvement in the production sector of the NE (Centro de Gestão e estudios estratégicos 2008). In the CS region, 50% of the sugarcane is mechanically harvested while in the NE manual harvesting still predominates in 95% of the areas. This is due to the uneven topography of the NE where 50% of the sugarcane production areas has slopes above 12%. Areas in the NE that have slopes lower than 12%, need to comply with the law whereby mechanization of harvesting is required by 2018. In the remaining areas, mechanized harvesting will theoretically be implemented by 2031. However, due to the lack of operational harvesting machines for steep slopes, the deadline to comply with the regulation in the areas with slopes steeper than 12%, is still not clear. The NE region stands out as the poorest region of the country with a high number of people living under the poverty line and a high rate of illiteracy. There is a need to develop the NE region to promote economic growth and to create job opportunities. Gaining more insight into the possibilities and challenges of the biofuel sector in the NE is essential to become as sustainable and competitive as the CS. Although international biofuels certification systems are present, socio-economic concerns around bioenergy production still exist in the NE region (de Carvalho Macedo 2005; Centro de Gestão e estudos estratégicos 2008) (Guilhoto et al. 2002; Ramos 2007) (Azanha Ferraz Días de Moraes 2007; Balsadi and Gonçalves Gomes 2008; Repórter Brasil 2008; Toneto and Bartocci Liboni 2008).

This research aims to demonstrate a methodology that quantifies key socio-economic impacts of the production of bioethanol in the NE, in particular the impact on GDP, imports and employment. The study uses input-output (IO) analysis as a tool to quantify the direct and indirect impacts of the new bioenergy activity. This methodology has previously been applied in several studies to analyse the impact of producing biofuel on amongst others GDP and employment; (Faaij 1998; Van den Broek et al. 2000b; Trossero 2006; Wicke 2009). Input-output analysis can be combined with bottom up field and process data to analyse e.g. direct and indirect employment effects of biofuel, which has been done for example for biodiesel and bioethanol production in Thailand (Silalertruksa et al. 2012). Because the sugarcane-ethanol sector uses different types of technologies, an IO model with mixed technologies was used. This methodology was first proposed by Cunha (2005) and it is described by Cunha and Scaramucci (2006). Using bottom up technology information in combination with an input-output analysis has also been performed by e.g. Neuwahl et al. (2008); they modelled employment impacts due to biofuel policies in the European Union. However, the studies that were mentioned look at country level (Brazil, Thailand), or even larger (EU-market). It is therefore not possible to obtain details on a regional level or even on different areas within one region.

Within the conventional IO analysis, an inter-regional approach is employed to be able to study the impacts in different regions. By using a bottom-up approach, scenarios with projections for 2020 have been drawn, that include not only traditional producing areas of the NE but also potential areas in which sugarcane production in the NE can be expanded. IO analysis allows assessing the economic linkages within the different provinces of the NE as well as studying the dependences of the studied region on the other Brazilian regions. Furthermore, it is possible to assess the different regional contributions to the total impact generated on the national economy.

In section 6.2, the methodology is explained, and the results are presented in section 6.3. Section 6.4 contains the discussion and in Section 6.5 the conclusions and recommendations are provided. Furthermore, the Appendices (Section 6.6) provide additional information on the sugarcane and ethanol sector in the NE (Appendix A), additional input for the scenario description (Appendix B), details on the construction of the extended inter-regional IO model (Appendix C), input data for the IO analysis (Appendix D) and detailed output results (Appendix E).

6.2 Methodology

6.2.1 IO analysis

Input-output (IO) analysis is widely applied to conduct national economic analyses and structural research, and is also used to assess macro-economic impacts of bioenergy production (Leontief 1963; Van den Broek et al. 2000a; Miller and Blair 2009; Wicke et al. 2009). The methodology allows for evaluating the impacts of new economic activities on a regional or national economy, by using IO tables. IO tables represent annual monetary flows of goods and services among different sectors in the economy. In this study, IO analysis is used to determine the impacts of sustainable sugarcane ethanol production in the NE of Brazil on *GDP*, *employment* and *imports*. A scenario approach has been deployed that includes different levels of yield, processing efficiencies and additional land for sugarcane cultivation (expansion land).

The direct value added or impact on GDP (V_{dir}), imports (M_{dir}) and employment (E_{dir}) are estimated from the correspondent impacts over the activities that are affected directly by the sugarcane-ethanol sector, while the indirect impacts relate to the indirectly affected activities, so that,

$\Delta V_{ind} = w_{nr} \Delta X$ (Equation 6-1)

$\Delta M_{ind} = m_{nr} \Delta X$ (Equation 6-2)

$\Delta E_{ind} = e_{nr} \Delta X$ (Equation 6-3)

where $w_{nr,}$ m_{nr} and e_{nr} are the normalized vectors of value added, imports and employment with the elements $w_{nr,i} = w_i/x_i$, $m_{nr,i} = m_i/ x_i$ and $e_{nr,i} = e_i/x_i$ respectively. Furthermore, *X* represents the total output, *i* represents the sector and *x* represents the output of each sector.

6.2.2 Extended inter-regional IO model

IO models are most commonly constructed to analyse socio-economic impacts of an activity on a country level. To be able to study a specific region and the relationship of the impacts among regions, an inter-regional model can be constructed, see e.g. Isard (1951) and Liang et al. (2007). The inter-regional model used in this research is derived from the single-nation model of Brazil by “disconnecting” the economy of the NE region from the rest of the Brazilian economy. However for the purpose of this study, two separate areas are differentiated within NE Brazil (traditional areas and expansion areas). Therefore, a total of three regions are distinguished (i.e. traditional areas, expansion areas and the rest of Brazil), making it an extended inter-regional IO model.

The regional disaggregation used in this study cover the following three areas: (i) *Traditional areas* of the NE; including the states of Alagoas, Pernambuco and Paraíba in which currently more than 80% of the total production of sugarcane in the NE takes place; (ii) *Expansion areas* of the NE; including all other smaller sugarcane producing states of the NE (Bahia, Maranhão, Piauí, Sergipe, Ceará and Rio Grande do Norte). In some of these states an expansion of sugarcane can take place as outlined in the Brazilian Sugarcane Zoning exercise (EMBRAPA solos 2009); (iii) *Rest of Brazil*; including all other Brazilian states (See Figure 6-1).

Figure 6-1: Regional disaggregation that is used in the extended inter-regional IO model of Brazil

The IO table used for this research was constructed by the Institute of Geography and Statistics of Brazil, and is based on the data in the tables of the Brazilian National Accounting System of 2004 (IBGE 2005b). More recent tables are not yet available, see discussion section. In order to build an IO table for the NE region, additional information was used from the Ministry of Work and from the Ministry of Development, Industry and External Commerce (Ministerio do Desenvolvimento 2008; Ministerio do Trabalho e Emprego 2008; Guilhoto et al. 2010). The employment figures and wages for each sector were based on data from the Institute of Geography and Statistics of Brazil (IBGE 2004). The original 64 sectors were aggregated to 34 sectors, including separate sectors for sugarcane, ethanol and sugar, see Table 6C-12 in Appendix C3.

6.2.3 Industry-based and commodity-based approaches

In order to introduce the technologies that are considered in the three scenarios of this analysis, the initial IO table was modified. One of the modifications is related to the introduction of technology-differentiated sectors; that is, different sectors applying different technologies to produce the same good (Cunha 2005; Cunha and Scaramucci 2006). For example, sugarcane can be manually or mechanically harvested, sugarcane can be irrigated or not, and ethanol can be produced either in a distillery or in a mixed sugarmill. This methodology permits accounting for different production systems to produce the same commodity. An example of this type of approach can be found in Appendix C1. In the extended IO model, the *industry-based technology* is applied for the technologies that only produce one commodity (e.g. sugarcane production, the ethanol produced in a distillery and the sugar produced in a sugar factory).

However, the industry-based technology approach is not the best if the production of one commodity in one sector can occur simultaneously with the generation of other commodities at the same proportion. For instance, in a mixed sugarmill, the production of ethanol occurs at the same time as sugar production and the production of electricity from bagasse. Therefore, the approach that takes this into account, called the *commodity-based technology,* is applied as well. See Appendix C2 for an example of this approach.

6.2.4 Technology differentiated sectors

There are 15 technologies included in the extended IO model, Table 6-5 at the end of this section lists these technologies together with the scenarios in which they are included. By including the 15 new technologies with the 34 sectors for the three different studied regions, the IO matrix used in this study is obtained. See Table 6C-13 in Appendix C4 which shows the structure of the model.

To introduce the new technologies that include changes in agriculture in the extended IO model, it is necessary to calculate the corresponding technical coefficients of production for the 34 sectors that are present in the IO table. The technical coefficients of production represent the ratio that gives the monetary value used in each sector per one monetary value worth of each output. These coefficients are calculated using production costs, provided in the Input Data Section. By dividing each individual costs by the total sugarcane production costs, the technical coefficients for each technology studied are calculated (see 6.6.4).

IO analysis commonly uses the final demand (Y) as exogenous variable and the production output (X) as endogenous component. This means that changes in the final demand are made outside the model and the IO model quantifies the effects of these changes on the economy's gross outputs. In some cases however, a mix of exogenous/endogenous components is more appropriate. This is the case in this study because the final demand for sugarcane ethanol is a result of a more sustainable and expanded sugarcane production. All final demand variables corresponding to each of the 34 sectors were considered exogenous except the final demand for ethanol ($Y_{ethanol}$) and sugar (Y_{sugar}), shown in Table 6-1. These two final demands were considered endogenous so the production output of ethanol ($X_{ethanol}$) and sugar (X_{sugar}), were exogenous components in this model.

Table 6-1: Exogenous variables considered in the extended inter-regional IO model for each region

Studied regions	Exogenous variables	Number of exogenous variables
Traditional areas NE	X etanol	34
	X sugar	
	32 Y's	
Expansion areas NE	X etanol	34
	X sugar	
	32 Y's	
Rest of Brazil	Y's	34
Total		102

The 15 newly introduced technologies result in 15 equations from which 6 equations are related to sugarcane production, 6 to ethanol production, 2 for sugar production and 1 for livestock production. Furthermore, the additional 34 sectors of the initial IO table lead to 34 basic equations of the IO model (AX + Y = X). Combining the 15 equations (for each of the two NE regions) with the 34 sectors of the IO table (for each of the three areas studied) gives a total of 132 independent equations, see Table 6-2.

Table 6-2: Number of equations used in the extended inter-regional IO model to solve the system

Technologies	Per region	Total (all regions)
Sugarcane	6	12
Ethanol	6	12
Sugar	2	4
Livestock	1	2
A.X + Y = X	34	102
Total equations		132

These 132 activities will lead to:

- 132 output variables in the IO model (X_1 to X_{132})
- 102 final demand variables (Y_1 to Y_{102})

Thus, the extended IO model uses a total of 234 variables, of which 132 are endogenous to the system and 102 are exogenous variables. All cost data and assumptions that are used to include the new technologies in the IO model are provided in the results section and appendix D.

The initial IO table gives information about the amount of employment generated as well as the average wages paid to the employees. The amount of employment per unit of production value is calculated using the following formula:

$$\text{Employment per production value } (Jobs/\ US\$) = \frac{technical\ coefficient\ labour}{12\ (months)\ x\ wage\ \left(\frac{US\$}{month}\right)} \qquad \text{(eq. 6-4)}$$

The technical coefficients of labour for each technology are provided in Table 6D-26 and Table 6D-27 in Appendix D. Wages per sector (sugarcane production, mixed sugarmill, distillery and sugar factory) are provided in Table 6D-22 in Appendix D.

6.2.5 Electricity production by sugarmills

Bagasse is a byproduct of sugar and ethanol production and can be used to generate electricity. In the results section the total amount of electricity that is generated at sugarmills is calculated by subtracting the value of the total electricity consumption of all sugarmills from the value of the total additional electricity produced by the mills (both values are provided by the input/output tables). This value is then divided by the producer’s electricity price (28.8 $/MWh), which is assumed to stay constant over time.

6.2.6 Sensitivity analysis

A sensitivity analysis is included in which the sugarcane yield and the amount of land on which sugarcane cultivation can be expanded are varied.

6.2.7 Data collection

Next to extensive literature reviews, interviews with a total of 35 people were carried out in Brazil, see Table 6-3. Data was collected during fieldwork (January- May 2011) in NE (Alagoas and Pernambuco states) and CS of Brazil (São Paulo state). In the NE region, three different sugarmills were visited. Due to the large amount of sugarcane outgrowers in the region, interviews were also carried out with the presidents of the outgrowers unions of Alagoas and Pernambuco. Another interview was performed with the president of Sindaçucar which is an association of 19 sugarmills of the state of Pernambuco and a central institution in the sugarcane-ethanol sector of the NE region. Numerous specialists in the sugarcane-ethanol sector who work in R&D centres and other technical institutions specialized in the sugarcane-ethanol field were interviewed. Finally, in order to gather information related to employment two non-governmental organizations and two unions of rural workers were interviewed.

Table 6-3: Interviewees of 6 different stakeholder groups

Type of group interviewed	Name (province)	Number of people interviewed
Sugarmills	Caeté (Alagoas)	4
	Coruripe (Alagoas)	6
	Pindorama (Alagoas)	4
Association of sugarmills	Sindaçucar (Pernambuco)	1
Outgrowers unions	ASPLANA (Alagoas)	1
	Outgrowers association (Pernambuco)	1
Experts and research centers	STAB (Alagoas)	1
	STAB (Pernambuco)	1
	RIDESA (Pernambuco)	2
	CTBE	5
	EMBRAPA	3
Worker´s unions	Union of rural workers of Coruripe (Alagoas)	3
NGO´s	Repórter (São Paulo)	2
	Solidaridad (São Paulo)	1

6.2.8 Scenarios for sustainable sugarcane-ethanol production in NE Brazil

The specific conditions found in the NE allowed for identifying potential improvements that can take place to achieve a more efficient and sustainable production and for making sugarcane expansion possible. This information has been used to define three different scenarios for 2020. The system boundary in the scenarios covers production and processing of sugarcane. The Business-as-Usual (BaU) scenario projects current management and performance of the production chain without significant changes. Two alternative scenarios, scenario A and B, consider the introduction of more advanced and efficient technologies that can increase agricultural and industrial productivities. Scenario B furthermore includes expansion of sugarcane production on additional land. Potential areas with high and medium productivity have been identified using the Sugarcane Zoning of the NE of Brazil (EMBRAPA solos 2009). Areas have been excluded where crops are being cultivated and only areas used for extensive livestock (with 1 to 2 heads/ha) are considered. Expected population growth was taken into account to determine the amount of pasture land needed to satisfy food consumption. The suitable areas sum up to 1.2 million hectares and they are located in the provinces of Bahia, Maranhão and Piauí. The current extensive livestock production system is considered to become slightly more efficient (passing from 2 to 3 heads/ha) which frees up enough land to cultivate sugarcane in the new expansion areas. The main technological changes that are included in the scenarios for the NE region are: implementation of irrigation, mechanical harvest of sugarcane and use of improved sugarcane species. The three projected scenarios are compared with the situation in 2010 (the reference scenario) to perform the IO analysis. The agricultural and industrial variables that define the different scenarios are summarized in

Table 6-4. Table 6-5 lists the 15 new technologies with the respective scenarios in which they are used. More detailed information about the structure of the sector and sugarcane, ethanol and electricity production in NE Brazil, can be found in Appendix A. In Appendix B more background information is provided about the compilation of the scenarios.

Table 6-4: Summary of parameters that define the scenarios used in the IO analysis

Parameters	Reference 2010	Scenario BaU 2020	Scenario A 2020	Scenario B 2020	Source
Land use (ha)	1,100,600	1,100,600	880,480 [a] (areas with slopes <18%)	880,480 [a] (traditional areas) and 1,249,607[b] (expansion areas)	(EMBRAPA solos 2009; Companhia Nacional de Abastecimento 2010)
Mechanical harvested areas (for traditional region in NE)	3%	50% (areas with slopes <12 %)	50% (areas with slopes <12 %)	50% (areas with slopes <12 %)	(ESALQ and USP 2009a; Companhia Nacional de Abastecimento 2010) (Torquato et al. 2008)
Mechanical harvested areas (for expansion region in NE)	1%	50%	50%	100%	(ESALQ and USP 2009a; Companhia Nacional de Abastecimento 2010)
Irrigated areas (ha)	-	-	308,168[c]	745,530 [c]	(ESALQ and USP 2009b)
Sugarcane yield (ton/ha)	57[d]	63[e]	97[f]	97[f]	(ESALQ and USP 2009b)
Ethanol yield (L/ton)	80.6[g]	80.6[g]	85.2[h]	85.2[h]	(ESALQ and USP 2009b)
Sugar yield (kg/ton)	135.5[g]	135.5[g]	140.3[h]	140.3[h]	(ESALQ and USP 2009b)
Electricity use in sugarmill (Kwh/ton cane)	-	-	75[i] (distillery) and 70 (mix sugarmills)	75 [i] (distillery) and 70 (mix sugarmills)	(BNDES and CGEE 2008b) (Industrial program of CTBE, fieldwork)

[a] Calculated by subtracting areas that have slopes higher than 18% (according to experts interviewed during fieldwork these areas represent 30% of the total area in the NE). Currently 7 million ha (out of 65 million ha of arable land) are cultivated with sugarcane in total Brazil (Martinelli et al. 2010).

[b] This scenario assumes an expansion of the sector in suitable areas of the NE region, as identified by the Sugarcane Zoning Maps of the NE of Brazil (EMBRAPA solos 2009). Only areas used for extensive livestock (with 1 to 2 heads/ha) are considered and expected population growth was taken into account. The suitable areas sum up to 1.2 million hectares and they are located in the provinces of Bahia, Maranhão and Piauí. The current extensive livestock production system is considered to become slightly more efficient (passing from 2 to 3 heads/ha). This means management is almost equal and therefore no change in employment and inputs in the livestock sector are taken into account.

[c] Calculated considering that only medium and large sugarmills, who currently own 35% of total cultivated area, will implement full and/or complementary irrigation.

[d] The average agricultural productivity of sugarcane production in the NE is around 57 ton/ha/year which is 26% lower than the national productivity due to its less favourable climate, poorer soils, uneven topography and often, poor management (Banco do Nordeste 2010). The structure of the sector is that 30% of the sugarcane production is cultivated by outgrowers (farmers who produce sugarcane and sell to sugarmills) and 70% by sugarmills (ESALQ and USP 2009b).
[e] Calculated by assuming an annual growth similar to the average of the last 20 years, which is 0.9%, see Figure 6B-5 Appendix B (IBGE 2009b). Furthermore, the same structure of the sector is assumed as in the reference scenario, see [d].
[f] The same structure of the sector is assumed as in the reference scenario, see [d]. Furthermore, improved sugarcane management is applied (more efficient use of agrochemicals and fertilisers) and improved sugarcane varieties are used. According to agricultural experts interviewed during fieldwork these changes could increase current sugarcane yields by 5.5%/year.
[g] Industrial process efficiency is assumed to be constant, no improvements have taken place in the last 15 years, see Figure 6B-6 in Appendix B (Ministerio de Agricultura Pecuária e Abastecimento 2009).
[h] An improved processing efficiency is assumed, due to modernization of industrial equipment. An annual growth of 0.56% (for distilleries) and 0.35% (for sugar factories) has been estimated (Verde Leal et al. 2010). A typical sugarmill in the NE uses 64% of the sugarcane for sugar production and 36% for ethanol production. Ethanol yield is depicted for a distillery (85.2 L/ton), but in a mixed sugarmill this is 30.7 L/ton. The sugar yield is depicted for a sugar factory (140.3 kg/ton), but in a mixed sugarmill this is 89.8 kg/ton.
[i] Surplus electricity is generated by bagasse-based cogeneration. The electricity that is used by the sugarmill for own consumption, is subtracted. 70 kWh/ton cane is used in the case of the distillery and 75 kWh/ton cane is used for a mixed sugarmill (interviews).

Table 6-5: Technologies included in the extended inter-regional IO model and the scenarios in which they are considered

No.	Technology	REF 2010	BaU 2020	A 2020	B 2020
1	Agricultural technology in 2010 with 100% manual harvest	V			
2	Agricultural technology in 2010 with 100% mechanical harvest	V			
3	Agricultural technology in 2020 with 100% manual harvest		V		
4	Agricultural technology in 2020 with 100% mechanical harvest		V		
5	Agricultural technology in 2020 with 100% manual harvest and higher technological levels (e.g. irrigation, better sugarcane varieties)			V	V
6	Agricultural technology in 2020 with 100% mechanical harvest and higher technological levels (e.g. irrigation, better sugarcane varieties)			V	V
7	Livestock production intensified (3 heads/ha)				V
8	Technology in 2010 in the sugarmills producing sugar	V			
9	Technology in 2010 in the distilleries	V			
10	Technology in 2010 in the mixed sugarmills	V			
11	BaU technology in the sugar factories in 2020		V		
12	BaU technology in the distilleries in 2020		V		
13	BaU technology in the mixed sugarmills in 2020		V		
14	Technological improvement for distilleries in 2020 (e.g. surplus electricity produced, more efficient equipment)			V	V
15	Technological improvement for mixed sugarmills in 2020 (e.g. surplus electricity produced, more efficient equipment)			V	V

6.3 Results

The IO analysis gives the change in total output (see the detailed Table 6E-28 in Appendix E, 0). This total output is multiplied by the GDP, imports and employment coefficients of the IO table to calculate the total impact of each of these variables. In Figure 6-2 and Table 6-6, the results for the NE region and Brazil for value added, imports and employment, are shown for the three scenarios.

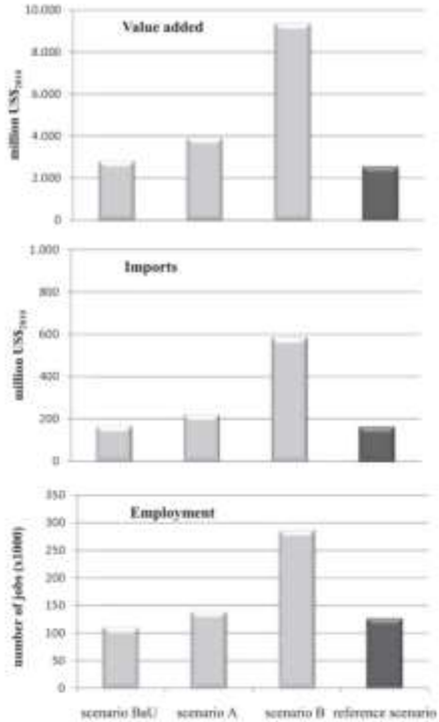


Figure 6-2: Total value added, imports and employment in the NE by the NE sugarcane-ethanol sector (traditional and expansion areas) in the scenarios BaU, A and B in 2020, compared with the reference scenario (2010).

The socio-economic impacts of the sugarcane-ethanol sector in the NE region in absolute figures per region and for Brazil, are presented in Table 6-6.

Table 6-6: Value added, imports and employment figures of all sectors per region and per scenario due to changes in the NE sugarcane-ethanol sector, in absolute and relative figures including the reference scenario

Area	Scenarios	Value added [million $US\$_{2010}$]	Relative impact* [%]	Imports [million $US\$_{2010}$]	Relative impact* [%]	Number of jobs (x 1000)	Relative impact* [%]
Traditional NE	Ref 2010	1.990		113		100	
	BaU2020	2.211		117		88	
	Scenario A2020	3,086		157		109	
	Scenario B2020	3.120		160		112	
Expansion NE	Ref 2010	547		49		26	
	BaU2020	602		51		23	
	Scenario A2020	831		67		29	
	Scenario B2020	6,236		424		174	
Rest of Brazil	Ref 2010	477		127		14	
	BaU2020	504		134		15	
	Scenario A2020	651		174		20	
	Scenario B2020	1,363		357		41	
NE Brazil	Ref 2010	2,537		161		126	
(trad+exp)	BaU2020	2,812	11	168	4	111	-12
	Scenario A2020	3,917	54	223	38	139	10
	Scenario B2020	9,357	269	585	262	286	126
TOTAL (Brazil)	Ref 2010	3.014		288		141	
	BaU2020	3.316	10	302	5	126	-10
	Scenario A2020	4,568	52	397	38	159	13
	Scenario B2020	10,720	256	942	227	327	133

*: Impact relative to reference scenario

Scenario B shows the largest impact on GDP, imports and employment. The results of scenario B also show that if an economic activity takes place in the NE expansion areas, different growth rates in value added, imports and employment are found in the other two studied areas. Here, the economy of the rest of Brazil is more favoured than the economy of the traditional areas of the NE because the CS region of Brazil produces a significant amount of the items used by the sugarcane sector in the NE region. In contrast, the traditional region (formed by the states of Alagoas, Pernambuco and Paraíba) has hardly any industrial activity. In the NE region most of the industry is concentrated in the expansion areas. Bahia has an important petrochemical complex (Camaçari) and a large car producing plant and the state of Ceará has metallurgic and cement sectors. This industrial activity supplies a significant part of the required items used by the sugarcane-ethanol sector in the whole NE region such as petrol and refined petroleum products and fertilizers and agrochemicals.

The breakdown of impacts by sector shows that the composition by impact type (direct and indirect) differs for each sector and per region, see Table 6E-29 in Appendix E. All sectors that provide inputs that are directly used for the production of ethanol and sugar in the NE are identified as direct impacts. Note that the impacts on the ethanol and the sugar sector in the two North-eastern regions are 100% direct (and 100% indirect in the rest of Brazilian regions) because the IO model constructed considers sugar and ethanol production in the NE as exogenous variables. The small contribution of indirect impacts in the sugarcane sector is because outputs of the sugarcane sector (seeds) are used as input. The electricity sector also has a big contribution on the direct effects because of the electricity produced in the sugarmills. It is observed that some items used for ethanol and sugar production in the NE region are provided by sectors located outside the NE region, mainly the sector that produces resin, plastic and other chemical products and the steel and metal producing sector.

6.3.1 Value added

All scenarios add value to GDP compared to the situation in 2010. The technologically advanced scenarios A and B, lead to higher impacts on GDP than the less progressive BaU scenario. Scenario B even leads to an increase of more than 250% compared to the reference scenario. The total GDP of Brazil was around 2,200 billion US$$_{2010}$ in 2010, while the total GDP of the NE region of Brazil is 14% of this amount which is just above 207 billion US$$_{2010}$. The relative impact of the scenarios, adds up to 1.3% to the GDP of the NE region in Scenario A and up to 3% in scenario B (and between 0.1 and 0.5% to the total national GDP in 2010 for all three regions combined).

6.3.2 Imports

In order to comply with the new ethanol and sugar demand studied in each scenario, the need for Brazil to import items increases, especially in scenario B, see Figure 6-2.

The Brazilian IO tables (IBGE 2005b) show that the main imported items for the sugarcane-ethanol-sugar sectors are: fertilizers, agrochemicals, machinery and equipment. Other sectors that use significant amounts of imported goods are the sectors: coke and refined petroleum products, fertilizer production and other chemical products, plastic and rubber products, steel and metal products and the machinery sector.

6.3.3 Employment

As shown in Table 6-6 a large amount of employment is generated in the NE by scenarios A and B while for the BaU scenario the number of jobs is reduced by 12% compared to the reference scenario. This is caused by the introduction of mechanical harvested sugarcane. When mechanical harvest increases from 3% to 50% (or a change from the reference scenario to the BaU scenario), the total number of jobs in Brazil is reduced by approximately 10%. In scenarios A and B, a reduction of employment by the sugarcane sector due to mechanical harvest also takes place but due to the large amount of jobs created in other economic sectors (e.g. transport) as a result of the additional sugarcane-ethanol-sugar produced, the total number of jobs increases compared to employment in 2010, even by 133% in scenario B.

The impact on the number of sugarcane jobs in the NE region (see Table 6-7) for scenario A shows that the negative impact of mechanization of sugarcane harvest on employment is larger than the positive impact related to the productivity gains. In scenario B this effect is only observed in the traditional areas. The additional land that is taken into production in this scenario leads to such job creation that the job reduction effect due to mechanical harvest is reversed.

Table 6-7: Change of employment in the sugarcane-ethanol sector in the three scenarios in absolute figures, compared to the reference situation (due to the introduction of mechanized harvest)

Area	Scenarios	Change in number of sugarcane jobs[a] (x1000)
Traditional areas NE	BaU	-16
	A	-7
	B	-7
Expansion areas NE	BaU	-4
	A	-2
	B	38
[a]: A negative sign indicates a job reduction		

A simulation was performed in the IO model where the two areas of the NE region are identical in their ethanol and sugar production as well as the technologies used. The results (see Figure 6E-8 in Appendix E) show a similar pattern, the direct impacts on GDP are larger in the two areas of the NE compared to the rest of Brazil. While the traditional area of the NE has slightly larger direct impacts than the expansion areas because of the presence of other industrial activities in these areas and the absence of these activities in the traditional areas.

The IO table gives also information about the average wages paid to the employees. The average salaries of employees in each sector differ per sector and per region. In general the salaries paid in most of the sectors of the expansion areas (varying from 142 to 6,550 US$/month) are slightly higher than those paid in the traditional areas of the NE region (varying from 58 to 5,577 US$/month), see Table 6E-31 in Appendix E for more details. However, the small difference found might be due to the marginal error inherent in the IO model and the data used and thus, the difference should not be concluding. On the other hand it is clear that workers employed in these two regions receive substantial lower salaries than employees in the richer CS region of Brazil. The total average salaries in the CS region are around 75% higher than those paid in the NE region of Brazil. The employees working in the sector of coke and refined petroleum products receive the highest wages (5,577 to 6,550 US$/month) while the employees of the livestock sector (126-308 US$/month) and other crop production (58-308 US$/month) receive the lowest wages. The sugarcane sector pays significantly higher salaries (135-362 US$/month) than the average salaries paid when cultivating other crops. The ethanol sector pays modest salaries (255-786 US$/month) compared with other industrial sectors but the salaries are slightly higher than in the sugar production sector.

6.3.4 Socio-economic impacts of capital investments

The results of the IO analysis do not take the effects of using capital goods to produce the amount of sugar and ethanol that is considered in each scenario into account. So, the effect of the production of capital goods is excluded.

New sugarmills have to be built and new machines and equipment have to be purchased if the additional sugarcane and ethanol is produced and processed. In the 10 years time period that is studied in the scenarios, old machines and equipment will also need to be replaced. The BaU scenario requires relatively small investments, between 160-660 million US$. The progressive scenarios A and B need significant funds: scenario A requires 1-4.5 billion US$ and scenario B 4.5-16.5 billion US$. The largest investment cost is required for the purchase of machines and equipment followed by construction costs (see Table 6E-30 in Appendix E).

The total socio-economic impacts are the sum of the impacts of producing ethanol and sugar and the impacts of the necessary investments to produce the additional ethanol and sugar, see Table 6-8.

Table 6-8: Breakdown of value addition and employment for traditional, expansion and rest of Brazil areas, due to the production of ethanol and sugar in the NE, combined with the related impacts of capital investments, for scenarios BaU, A and B*.

	Total value added (billion US$$_{2010}$)			Total employment (x1000)		
	BaU	A	B	BaU	A	B
Traditional areas NE	2.2	3.1	3.1	88	110	112
Expansion areas NE	0.6	0.8	6.3	23	30	175
Rest of Brazil	0.5	0.9	2.5	17	31	82
TOTAL	3.3	4.9	11.9	128	170	370

*Numbers may not add up due to rounding

Since most of the machinery, equipment, vehicles and the construction services are provided by the CS region, this area absorbs quite a large share of the impacts generated by the investments made in the NE region, see Table 6E-29 and Table 6E-30 in the Appendix for more details. The employment generated by the investments made is large, reaching almost 43,000 jobs in scenario B (11,000 in scenario A and 2,000 in the BaU scenario). Compared to the reference scenario, the total employment including capital goods investments, employment is increased with 21% and 164% in scenario A and B respectively, and decreased with 9% in the BaU scenario. Scenario B would add value of around 0.5 % to the national GDP of Brazil and around 4% to the GDP of NE Brazil.

Depending on the scenario, the surplus electricity that can be generated by the sugarmills, 5.5 and 13.6 TWh in scenario A and B respectively, represent around 9% to 22% of the total electricity produced in the NE region nowadays (61 TWh in 2009). Potentially 10 to 25 million people can benefit from this in the NE region (Ministry of mines and energy 2007).

6.3.5 Sensitivity analysis

Two parameters are varied:

- *Values of sugarcane yields*: Since irrigation has demonstrated to be the factor that contributes the most to the change in yields, the analysis is performed for different irrigation ranges. It is assumed that only large to medium sugarcane producers can afford the investment required for irrigation systems, who cover 35% of the total area, this relates to average sugarcane yields of 97 tons/ha/yr. As a conservative estimate, an area of 10% is assumed, relating to an average sugarcane yield of 89 ton/ha/yr. An upper range is assumed taking into account that policy programs facilitate and promote irrigation systems for smaller sugarcane producers, covering 50% of the area which relate to average sugarcane yields of 103 tons/ha/yr.
- *Amount of expansion land*: The amount of additional land for sugarcane cultivation in the future depends on many factors, e.g. policies, financial resources and evolution of the sugar and ethanol demand. 50% of the expansion area of scenario B is used as lower limit (625,000 ha). The upper range includes all potential expansion areas identified by the sugarcane Zoning exercise which is 2 million ha (EMBRAPA 2009).

The results are presented in Figure 6-3.

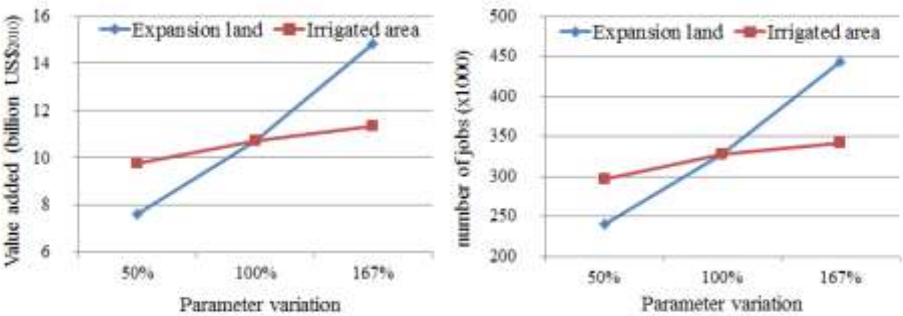


Figure 6-3: Variations in value added and employment using a range for irrigated areas and expansion areas

The sensitivity analysis shows that the results of the IO model are highly dependent on the amount of expansion land that is considered. Varying the amount of land from 624,000 to 2 million ha causes GDP to vary from 7.6 to 14.8 billion US$$_{2010}$, while employment varies from 240,000 jobs to 443,000 jobs. The amount of irrigated area (and thereby yield) has a much less effect on GDP and employment. This is due to the fact that the total additional production of sugarcane is much larger considering the total amount of expansion land compared to the yield change due to irrigation. Even at the lower range, so if 50% of the expansion land is considered (624,000 ha of land) this still leads to positive impacts on GDP and employment.

Other studies that use a similar methodology show that employment effects from the production of biofuel can indeed be large, although assumptions are generally very different. The study by Wicke et al. (Wicke et al. 2009) on soy production in Argentina found an employment increase of 16-21% (2-2.7 M jobs) and total GDP increases by 16-25%.And in Thailand biofuel production can generate around 118,000 person-years (direct and indirect) based on biodiesel and ethanol production in 2009 (Silalertruksa et al. 2012).

6.4 Discussion

6.4.1 Input-Output analysis

An IO analysis can provide useful and quantifiable outcomes on value added, imports and employment. However, there are also several drawbacks that are inherent to this methodology, described by e.g. (Wicke et al. 2009; Allan 2011). Another methodology that could be used is a General Equilibrium Model (CGE) such as described by e.g. (Scaramucci et al. 2006). But CGE models are more complex and require high capacities. When using inter-regional IO models, a large amount of intra and inter-regional data is needed and it is necessary to make assumptions on the dependability of interregional trading relationships. Other uncertainties associated to inter-regional models include allocation, aggregation, imputation and balancing compared to one-single region models (Miller and Blair 2009; Wiedmann 2009).

An IO table of 2004 is used to calculate the socio-economic impacts of the situation in 2010 and thus, it is assumed that the economy and the inter-sectoral linkages stay the same in the given period of time. This is a rather strong simplification because economic changes have occurred since then, for example the global financial crisis in 2007-2008. Although the Brazilian emerging market withstood the international financial crisis well, the growth in GDP fell in 2008 and 2009 and many companies had to cut their production levels and cancelled or postponed investment projects. Thus, it is uncertain whether the 2004 IO table is representative for the economic structure nowadays and it is even more uncertain for scenarios in 2020. It is therefore recommended to use more updated IO tables when applying IO analysis for medium- to long-term time periods. Furthermore, to simplify the model, the producers electricity price is assumed to remain constant, which in reality may be different. Also other prices are considered constant in an IO model, taking a learning curve into account could improve the model. This also counts for the fixed technology coefficients, that assume constant returns to scale as explained also by (Allan 2011).

Other uncertainties are found in the disaggregation of the different expenditures which are allocated over the different IO sectors of the model. Due to the lack of published data this was mainly based on expert's estimations and thus, there is a margin of error in the disaggregation. However, this error is not expected to change the results significantly since the contribution of the costs that were disaggregated (e.g. agricultural inputs and repair and maintenance (R&M) costs) to the total production costs is not large.

The IO model used in this study has not considered the domestic consumption induced by new economic activities that are generated, since the initial IO tables embedded the domestic consumption data within the final demand column. Therefore, it is expected that when accounting for these induced impacts, the socio-economic impacts will be more positive than the ones presented in this research. For future research, Brazilian IO tables could be improved by separating imports and household consumption from the added value row and the final demand column respectively. This will allow calculating the impacts on trade balance and the induced effects on the economy

Although the extended inter-regional IO model developed can deliver a large amount of information (e.g. GDP and employment changes in all economic sectors of each region, income levels etc.) it cannot quantify other key socio-economic aspects. For example, the quality of labour, land conflicts and migratory issues are essential issues that will need to be tackled in a comprehensive socio-economic assessment. Furthermore, it is highly recommended to further study food competition issues and the environmental implications of expanding sugarcane.

Detailed cost-benefit analyses of the implementation of irrigation in the different producing regions of the NE are essential. This can help to gain more insight in the potential of this technology and can also attract the attention of investors and promote favourable governmental policies. It is also recommended to collect additional production costs data at a regional level to be able to assess the accuracy of different data sources together with potential yields that the sector in the NE region can achieve.

6.4.2 Input data and assumptions

While the biggest socio-economic impacts are found in scenario B, it is more likely that in the coming years a growth-path is established that resembles scenario A. Most of the interviewed people agreed that the growth in the sugarcane-ethanol-sugar sector in the near-term will occur vertically (improving yields) and not horizontally (expanding land). Although in the NE region there are potential areas to grow sugarcane, as identified by the Agroecological Zoning, the better conditions of the CS (more water availability and larger pieces of land) attracts currently the biggest investors. Sugarcane producers of the NE are already expanding their businesses in areas of the CS. However, with the implementation of favourable policies and investments, scenario B can become a reality. In fact, some initiatives are now being developed in Maranhão (SINCOEX program) and Bahia (project Bahia Bio) to expand the sugarcane-ethanol sector (Jornal Cana 2006). Furthermore, the resources for investments already exist in the region. Beyond those offered by the governments of the states and by the BDN (Bank of the NE), the Federal state also helps entrepreneurs through the BNDES (Development Bank) and private funds. The direct involvement of foreign capital has also played a key role in the Brazilian sugarcane-ethanol sector. The NE has available fertile land for sugarcane cultivation together with inexpensive land prices and good access to infrastructure which are key factors from an investor's point of view.

The scenarios have assumed a certain sugar and ethanol production; however there are several aspects that influence this. The NE has become essentially a sugar producer due to the high international sugar prices and the export incentives the producers receive in the NE. This has retained the ethanol market to grow. Although international sugar prices are anticipated to remain high, it is uncertain whether the favorable quotas will continue. Ethanol is mostly consumed in Brazil and its prices are sensitive to the domestic market and idiosyncratic factors such as the evolution of the flex-fuel cars market, climate and the existence of credit (Kanadini Campos 2010). The tendency of higher petrol prices together with an increasing interest for biofuels due to environmental concerns will push the demand for ethanol, creating an opportunity for the ethanol market in the NE to grow. However, the possibility to produce sugar or ethanol by mixed sugar mills, has a positive influence on the stability of income because the mills can switch production depending on the best price.

The scenarios in this analysis have only included sugarcane-ethanol production. The production of second generation ethanol from bagasse and straw is an option with large potential. Another scenario where the sector shifts from sugarcane production to other crops could also occur. However, this is not very likely because farmers in the past have tried to do so and they returned to sugarcane because it was more profitable.

The rate of mechanical harvest assumed in each scenario can vary. It is still not clear how and when the full prohibition of manual harvest will affect the hilly regions of the NE region. Amongst other reasons due to the lack of financial resources and political support in the region essential to facilitate the shift to mechanized harvesting. Lower mechanization rates than the ones considered here will lead to less low paid jobs lost. Moreover, also wages and prices will change during this time period and hence the total impact might be larger than calculated.

By introducing higher technological levels in the sugarcane-ethanol sector, two distinct impacts might be generated; on wages paid and on the informal economy. More higher-qualified labour, as required in scenarios A and B, will have higher average salaries compared to the reference case, which is positive. But, higher technological levels such as a higher mechanization rates, will negatively impact low-qualified workers, who might move to informal employments in the absence of a better job. To avoid this, it is essential to ensure training programs to enable low-qualified labour to access more stable and better paid jobs. However, further research is needed to understand the relationship between the current informal economy and the impacts of introducing higher technological levels in the sugarcane sector in Brazil.

The production of surplus electricity from bagasse can considerably increase the sector's revenue in the future as well as being an important contribution to the region's electricity matrix. Moreover, this can provide the additional electricity needed to irrigate the sugarcane. The high levels of fibre in the sugarcane grown in the NE together with the gradual elimination of sugarcane burning would increase the potential to generate electricity from bagasse and straw. However, a main obstacle to achieve this could be the lack of investments. Also, the small-scale production size of most of the plants in the region limits the possibilities of introducing technological improvements and increases the production costs.
A limitation of the scenarios constructed is the omission of the technological changes occurring in the sugarcane-ethanol sector of areas outside the NE region such as the CS where the productive systems are also expected to improve in the coming years. When accounting for this, the calculated impacts, in particular value added, will be larger than the presented results. Furthermore, the efficiency improvement in the livestock sector was highly simplified, this should be analysed further.

An important aspect is the large variation of the outcomes of this study by the amount of land considered and that surplus land may only become available with an intensified livestock system which requires favorable policies and the arrival of the required financial resources in the sector. Since no intensification trends of livestock production have been observed in the past years, it is essential, when considering biofuels expansion, that adequate policies and investments are implemented to achieve a more efficient livestock production without food displacement effects.

The Sugarcane Zoning (ZANE) used to identify new sugarcane areas has only been approved as a law proposal and thus, all the protected areas that the ZANE excludes are actually not fully protected yet.

6.5 Conclusions and recommendations

All scenarios studied increase the GDP and imports of the region compared to the current situation. In 2020 the value added by the sugarcane ethanol sector of the Northeast (NE) region reaches up to 2.8 billion US$ (BaU scenario), to almost 4 billion US$ (scenario A) and to 9.4 billion US$ (scenario B), where the expansion areas of the NE experiment the largest growth. The impact of the sugarcane sector in the NE on the total GDP of Brazil varies from 0.2% in the BaU scenario up to 0.5% in scenario B. The potential electricity that can be generated is huge, reaching up to 9% (scenario A) and 22% (scenario B) of the total electricity currently produced in the NE region. The analysis showed that the negative impact on employment by introducing mechanical harvest is counterbalanced by the positive effects of productivity gains, the total employment in the NE region in 2020 increases with 10% in scenario A (around 12,500 jobs) and 126% in scenario B (around 160,000 jobs). A large part of the employment created will take place in the sugarcane sector. Since the newly generated jobs will require more qualified labour, complementary efforts to boost educational programs to the low-educated workers, mostly present in the sector and in the region, are desired.

The inter-regional analysis has shown that a large part of the GDP that is generated goes to those states where most industrial activities are located (due to indirect effects), which is the Central South (CS) region. Most of the machinery, equipment, vehicles and services are provided by the CS. This means that if the current situation continues, any development in the producing states in the NE sector will not fully benefit the region because of the large dependency of the NE on the economic activities in the CS region. The little industrial activities occurring in the NE need to grow so the region can become more economically independent from the CS of Brazil.

This study has used an inter-regional IO model which has proved to be an adequate tool to assess the socio-economic impacts in the studied region and in the other Brazilian regions. It has permitted to develop a deeper understanding of the linkages within and outside the NE region. The extended model uses a more complex approach than a conventional IO analysis by using technologically different production systems and an exogenous/endogenous model. Despite the uncertainties of the method discussed before, the approach used is a good and robust tool to calculate the regional and national socio-economic impacts of different sugarcane-ethanol production systems.

The NE region has potential to be a new frontier for sugar and ethanol production. The positive socio-economic impacts that occur while developing and expanding the sector in the NE region are very large for the region and for the economy of the rest of Brazil. If the sector could be stimulated and expanded without hampering food production and causing further pressure on the land and the environment, the sugarcane-ethanol market in the NE could achieve a level of technology and sustainability as high as in the CS. This will substantially encourage regional development and economic growth.

6.5.1 Specific outcomes and recommendations for the region

There is a need for more R&D programs that can promote local solutions to the sector in the NE. Until now the NE region only tried to follow and adapt to the developments made in the CS region. Exogenous solutions from other regions have not always shown to be viable and have the same benefits for the NE region. Thus, the strengthening of R&D programs are essential, particularly in matters relating to agriculture where the correct understanding of the local factors has shown to be key in the sector's development.

Strengthening the industrial sector of the NE will reduce its dependency of the CS region, which will generate more wealth and employment locally. A stronger focus on exporting the ethanol and sugar produced to the international market to take advantages of the lower transportation costs of the NE region in compared to the CS. This could place the NE region in a more competitive position.

To ensure the accomplishment of sustainability standards in the sector, effective certification is needed. Certification should result in a win-win situation among the various actors of the supply-demand chain where a price premium paid by the demand side is received by the producers when they comply with the standards.

An increasingly common practice among producers is the rotation of sugarcane with other (food)crops such as soybeans, peanuts and beans. This enables farmers to diversify their income and is also recommended to maintain good soil conditions.

It is also vital to study and implement solutions that cushion the negative impact on labour from the introduction of mechanization. Programs to train low-qualified labour, like currently in São Paulo, are needed. The lack of agricultural knowledge among small sugarcane producers can also be avoided by adequate training programs.

Because of the obstacles to generate electricity by small scale plants, a reorganization of the sector by grouping the smaller units into large scale plants could bring numerous benefits to the sector such as increased electricity production for the region.

Acknowledgements
This research project was partly funded by NL Agency, in a project carried out with Solidaridad. Furthermore, the 4 month fieldwork at CTBE in Campinas and in the Northeast of Brazil was facilitated by the Global-Bio-pact project which is supported by the European Commission in the 7th frame work programme under contract number 245085. We would like to express our appreciation for all help received during the data collection and fieldwork. In particular, from all people at CTBE who provided very useful information and all interviewed people during field work (Emídio Cantídio and the people interviewed in the sugarmills Coruripe, Pindorama and Caeté, União dos Trabalhadores Rurais de Coruripe, Asplana, STAB Alagoas, Sindicato dos trabalhadores de cana de Pernambuco, Ridesa, Sindaçucar, Embrapa and Reporter Brasil). Furthermore we would like to thank Birka Wicke for her valuable input on the methodology and two anonymous reviewers who provided useful feedback.

6.6 Appendices to Chapter 6

6.6.1 Appendix A: Structure and description of the sugarcane-ethanol sector in the NE of Brazil

6.6.1.1 Structure of the sugarcane-ethanol sector in the NE of Brazil

In the NE region the production of sugarcane is located on the eastern coastal tableland called *Zona da Mata*. This area is the second biggest sugarcane production area in Brazil (and the fourth world biggest sugarcane producer) contributing with 10%, 12% and 7% of Brazilian sugarcane, sugar and ethanol output in 2010 respectively (Centro de Gestão e estudios estratégicos 2008; Companhia Nacional de Abastecimento 2011). The states of Alagoas and Pernambuco are the main producing regions with 72% and 85% of the regional sugarcane and ethanol produced in the NE respectively (Companhia Nacional de Abastecimento 2011).

The sugarcane produced in the NE is cultivated either by outgrowers or by medium and big producers (usually sugarmills). In the NE more than 90% of the sugarcane producers are small units owning less than 20 ha but producing less than 5% of the regional sugarcane produced. Most of the outgrowers cultivate the sugarcane until it is ready to be harvested and then sell it to the sugarmills who take the responsibility of other operations such as processing. Although agricultural yields in the NE are currently still low compared to yields in the CS region; better fertilization, the introduction of irrigation and the use of improved sugarcane species, among other factors, have largely contributed to increased agricultural yields in the last 20 years (IBGE 2009b).

The sugarcane that is produced, is processed in 76 sugarmills located in the NE region. Sugarmills can broadly be classified into three groups; (1) Sugarmills that only produce sugar, which represent 9% of all plants; (2) Sugarmills that can produce both sugar and ethanol. This is the dominant group representing 57% of total plants (3) Independent distilleries that only generate ethanol, which account for 34% of all the plants (Ministerio de Agricultura Pecuária e Abastecimento 2009). The large proportion of small sugarmills, processing 500,000 ton or less, restrains the competitiveness of the sector in the NE compared to the CS.

The states of Alagoas, Penambuco and Rio Grande do Norte are more oriented to sugar production while all the other smaller sugarcane producing regions focus more on ethanol production. From the current 63 Mton sugarcane produced in the NE, 60% is dedicated to sugar production. Often production of ethanol in Northeast sugarmills is marginal and it is only produced to use the molasses obtained as a byproduct during sugar production. This is due to the favourable sugar export quotas the NE region has and the current high world sugar prices generated after the past water flows in important sugar producing countries such as India and Pakistan (experts, fieldwork).

6.6.1.2 Description of sugarcane production in NE Brazil

Planting

In the NE the sugarcane is normally planted shortly after the previous harvest and is harvested in the next year, so after 12 months. The planting period is between September and February (ESALQ and USP 2009a). In the CS on the other had, sugarcane is usually planted in cycles of 18 months, with a fallow period or rotation crop in between.

The uneven topography of the NE makes it sometimes difficult to mechanize some of the operations. The three types of areas where sugarcane is cultivated in the NE can be classified as follows:

1. Flat areas called "chã' which are good areas for sugarcane cultivation. It is possible to mechanize all the operations (planting, fertilization, harvest) as well as using precision agriculture, having a good management of nutrients, and to irrigate. Here productivities of 80 ton/ha are easily reached.
2. Hilly areas called "costa" which are frequently found in the North of Alagoas and Pernambuco and reach slopes up to 40%. In very steep areas (>18% slope gradient) all the operations of preparation of the soil, fertilization and harvesting need to be done manually which increases significantly the labour costs and therefore, the final production costs. Here productivities are 50 ton/ha and lower. Besides, the sugarcane collected in these areas has lot of impurities and requires more washing which leads to more losses of the total reducible sugars than that cane cultivated in flat areas. These areas are considered inappropriate for the cultivation of sugarcane
3. Shallow areas closer to the sea side which are called "varzea" which are flat areas but their proximity to the sea side soils are often wet making difficult to use mechanical harvest. Here moderate to high productivities (up to 80 ton/ha) can be reached

Fertilization

Sugarcane demands high amounts of nutrients. In order to improve the quality of the sugarcane and sugar yields on a sustainable basis, it is essential to apply adequate amounts of nutrients (N, P and K). The application of ferti-irrigation, where industrial waste (stillage and filter cake) are used as fertilizers, decreases the consumption of traditional fertilizers and has proven to improve yields (de Carvalho Macedo 2005).

Weed and pests control

In order to avoid yield losses it is essential to use products that combat diseases, pests and weed growth. The methods to avoid germination of weeds vary depending on the slope of the cultivated area. In flat areas, it is common to reduce the spacing for weed control. Mechanized harvesting can also reduce the use of herbicides because when the sugarcane is not burned, the straw stays on the soil surface and avoids the germination of weeds.

Irrigation

Sugarcane has a high water requirement in comparison to other crops. The water demand is estimated to be between 1,100-1,500 mm with an evapotranspiration rate of 4-7 mm/day. Water supply, especially during critical stages, is essential to ensure good agricultural productivities.

While most of the sugarcane cultivated in the CS region of Brazil does not need to be irrigated due to the frequent rains, sugarcane irrigation in the NE region is an essential factor. The sugarcane is cultivated in the coastal regions (Zona de mata) where the average annual rainfall is 1500mm. However, the rainfall is heavily concentrated between March and May. If water could be captured during this 3 month period, this would be sufficient for irrigation during the dryer period. Experiments executed by by Embrapa in asugarmill located in Piauí, have demonstrated the potential of irrigation in the NE; yields have increased more than 2 times (Andrade et al. 2009). Currently most of the sugarcane in the NE is cultivated using salvation irrigation: water (<200 mm) is supplied during critical periods to prevent water deficits. The most commonly used systems are sprinkler systems with wheel-line and pivot systems. Drip-irrigation is only used by large sugarmills due to its high investment cost. Another type of irrigation is ferti-irrigation: vinasse (a by-product from the ethanol production process) is used in a drip-irrigation system, in this way both fertilizers and water is provided to the sugarcane. Areas with high slopes are normally not irrigated due to the difficulty of implementing an irrigation system. More and more sugarcane in the NE is being irrigated, the irrigated area of the *Coruripe* sugarmill for example, has grown from 2,700 hectares to the current 25,000 hectares in 25 years.

Improved sugarcane species

Improved sugarcane varieties adapt to the climate conditions, soil type and harvesting system (manual or mechanized) of the different regions. They are also resistant to pests, diseases and water stress as well as having high concentration of sucrose in the storage tissue (Galvão et al. 2005). The main sugarcane varieties grown in the NE are RB and SP varieties which account to more than the 80% of the region´s inventory. A very successful variety found recently is RB 92579 which is resistant to drought and can be cultivated in steep slope areas. This variety has proved to improve productivities with 30% and increase the sucrose content of the sugarcane in 20% (research centre, fieldwork).

Harvest

The whole sugarcane cycle in the NE region is typically a 5 years-cycle which includes 4 harvests. However, in fields with high slopes it is common to replant the sugarcane after 4 years, while in flatter areas the sugarcane cycle can reach 8 to 12 years. Throughout these cycles the productivity decreases and therefore, it is normally more cost-effective to replant the crop after on average 5 years. The harvest season typically starts in

September and ends in March. Depending on the sugarcane variety the first harvest is made after 12-18 months of planting.

6.6.1.3 Description of sugar, ethanol and electricity production in NE Brazil

Processing

When the industrial yields are compared with those obtained by the CS region, it can be said that the sugarmills in the NE are slightly less efficient in the conversion of sugarcane to ethanol due to the lower technological levels and the poorer quality of the sugarcane processed. The sugarcane cultivated in hilly areas has often less TRS. This is because this sugarcane drags more impurities when it is being harvested which needs more washing and thus, increasing the sugar loss. The industrial losses of the sugarmills in the NE are around 11% while in the CS the average is 8%.

Electricity generation

Sugarmills need three kinds of energy to process the sugarcane: (1) thermal energy for heating and concentration processes; (2) mechanical energy for milling and other mechanically driven systems (pumps and large fans) and (3) electric power for powering pumping, control systems and lighting. This energy is provided by co-generating bagasse in the mill´s boilers. In areas where mechanical harvest is implemented, sugarcane straw can be also used as a fuel but this new practice is not being used in the NE region yet.

The processing of one ton of sugarcane yields about 140 kg of dry bagasse that can generate 500 kg to 600 kg of steam where approximately 400-600 kg of steam or 12 kWh per ton of sugarcane processed are consumed in the industrial process (BNDES and CGEE 2008b). The bagasse obtained in the NE region has 12% more fibre content than the bagasse from the sugarcane cultivated in the CS region which is an advantage for the electricity generation process (Centro de Gestão e estudios estratégicos 2008). Sugarmills sometimes use the surplus electricity produced to sell in the energy market and also to consume in the agricultural process when irrigation is implemented. It was found that sugarmills in the NE using irrigation prefer to sell all the surplus electricity generated and buy the electricity needed for irrigation since this is more profitable (sugarmills, fieldwork). Currently the amount of plants in the NE area selling their exceeding energy is negligible. Sugarmills in the NE region can be considered small to medium units having an installed capacity of less than 30 MW (Ministerio de Minas e Energia and Empresa de Pesquisa Energetica 2010) ; research centre, fieldwork). There are in total 38 sugarmills in the NE that have electrical capacity installed. 17 sugarmills that have an installed electrical capacity <9 MW, 16 of 10-29 MW and only 5 30-60 MW (Ministerio de Minas e Energia and Empresa de Pesquisa Energetica 2010) ; research centre. Units located in the CS region have 60 to 100 MW installed capacity.

6.6.2 Appendix B: Additional data for scenario descriptions

6.6.2.1 Business-As-Usual scenario

In order to project growth tendencies for this scenario the historical evolution of sugarcane production and of the area cultivated are taken into account, see Figure 6B-4. Between 1990 and 2000, cultivated land and sugarcane production in the NE of Brazil rapidly decreased. During this period, many sugarcane producers stopped production because of the difficulties trying to compete with the CS producing region. From 2000 to 2009 a slow recovery of the sector took place.

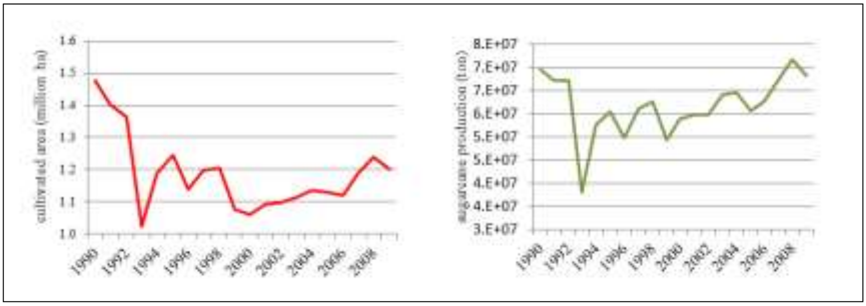


Figure 6B-4: Evolution of cultivated area with sugarcane in the NE since 1990. Elaborated with data from IBGE (IBGE 2009b)

The recuperation was slightly faster in the last years because of the expansion of sugarcane in Rio Grande do Norte, north of Alagoas and Paraiba and because of the slightly better agricultural practices (e.g. use of improved sugarcane species). These changes are reflected in the yields which have increased in the past 20 years (between 1990-2009) with on average 0.9 %/year, see Figure 6B-5.

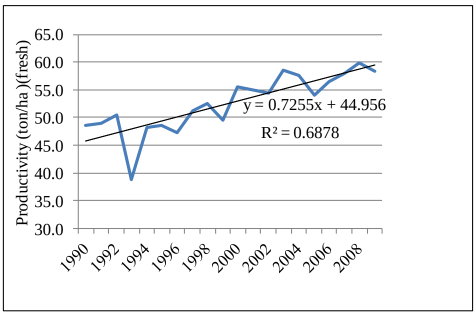


Figure 6B-5: Evolution of sugarcane productivity in the NE since 1990.Elaborated with data from IBGE (IBGE 2009b)

Regarding the industrial yields, no improvements have taken place in the last 15 years as depicted in Figure 6B-6. Yields remained at 80.6 L/ton for ethanol production (for distillery) and at 135.5 kg/ton for sugar production (for sugar factories).

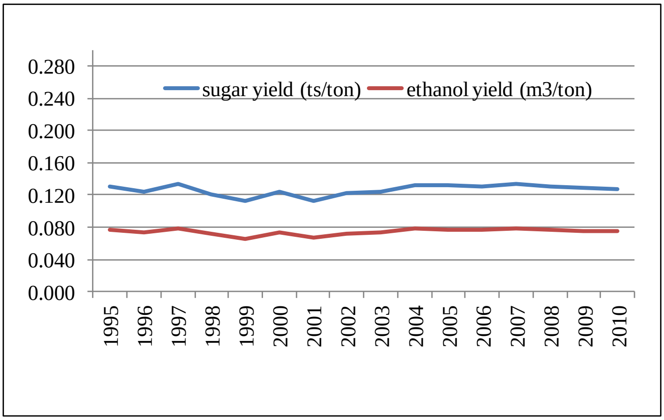


Figure 6B-6: Evolution of sugar and ethanol yields in the NE region from 1995. Calculated from data from association of sugarmills (fieldwork) and data from (Ministerio de Agricultura Pecuária e Abastecimento 2009)

The same configuration of sugar and ethanol production in each sugarmill is maintained, see Table 6B-9. This is used in the IO model to distribute the total production of sugarcane, sugar and ethanol among the different plant types. Sugarmills will have an average processing capacity of 1,100,000 ton of sugarcane. In sugarmills that produce ethanol and sugar (mixed sugarmills) 64% of the sugarcane is directed to produce sugar and 36% to produce ethanol. From the total sugarcane produced, 59% is used for sugar production and 41% for ethanol production as currently practiced in the NE region.

Table 6B-9: Current share of sugar and ethanol production of each type of sugarmill

	Sugar factory	Distillery	Mix sugarmill	Source
Sugarcane milled	11%	32%	57%	(Companhia Nacional de Abastecimento 2010)
Sugar production	24%		76%	Own calculations[a]
Ethanol production		61%	39%	Own calculations[b]

[a] Calculated using the sugarcane milled in each plant type and a sugar yield of 135.5 kg/ton cane (for sugar factory) and of 86.7 Kg/ton cane (for mix sugarmill)

[b] Calculated using the sugarcan milled in each plant type and an ethanol yield of 80.6 L/ton cane (for distillery) and of 29L/ton cane (for mix sugarmill)

6.6.2.2 Scenario A

Key parameters that influence productivity in the NE are irrigation and the use of improved sugarcane species (Centro de Gestão e estudios estratégicos 2008). Two types of irrigation methods are assumed in this scenario; drip irrigation which is most efficient in water and energy consumption but is also more expensive, and sprinkler-irrigation systems which are cheaper but are less water and energy efficient. In 2020 it is assumed that drip-irrigation and sprinkler irrigation will be implemented in 30% and 70% of the total irrigated area respectively. Furthermore, rain-water capture installations are assumed to be built that supply the total amount of irrigation water that is required. The energy needed for the irrigation system will be provided by the electricity generated from bagasse. Thus, only the large and medium sugarmills will implement irrigation in their production systems, because this investment is too high for small producers. Therefore, only 35% of the total cultivated area will include supplementary and full irrigation. The rest of the areas maintain salvation irrigation (160 to 200 mm) as currently practised.

Ferti-irrigation provides a solution for better water and fertilization management since water and fertilizers are delivered to crop simultaneously through the drip irrigation system. In this study is it assumed that that the current levels of fertilizers and agrochemicals do not need to necessarily increase to enhance yields but they can be more efficiently used by having better agricultural management.

The total cultivated area in this scenario has excluded all those areas with slopes higher than 18%. This is done because high slopes areas are economically unfeasible for the cultivation of sugarcane on a large scale due to: (1) Impossibility to implement mechanical harvest with the technology that currently exists (2) These areas are inaccessible and need frequently intensive use of labour for other operations such as tilling, planting, fertilization and irrigation which increases the cost of production (3) The sugarcane in these areas has many impurities which needs more washing and results in the correspondent loss of the total reducible sugars. Areas with slope gradients higher have been estimated to represent 30% of the total area by experts during fieldwork. Then total sugarcane area considered in this scenario is 0.88 million ha (30% of the current 1.1 million ha).

By combining all the aspects explained above the potential productivities that can be achieved are very large. Table 6B-10 depicts the projected productivities considered for this scenario. A division has been made in (1) Areas belonging to small producers that use salvation irrigation (5.7 thousand ha or 65% of total area) and (2) Areas belonging to large and medium producers that incorporate supplementary and full irrigation (3.1 thousand ha or 35% of total area).

Between 2010 and 2020 the annual growth rates for the medium/large and small sugarcane producers are 7% and 4% respectively. These yields have been estimated on what is currently being achieved by using some of these practices and by consulting agricultural sugarcane experts during fieldwork.

Table 6B-10: Current and projected sugarcane yields (ton/ha/yr) in 2020 for scenario A

Year	Areas with salvation irrigation, use of	Areas with supplementary and full	Average

	better sugarcane species and more efficient fertilizers and agrochemicals use (65% of total area)	irrigation, use of better sugarcane species and more efficient fertilizers and agrochemicals use (35% of total area)	productivity
2010	57	57	57
2020	85	120	97

The level of mechanical harvest in this scenario for 2020 is 50% that corresponds to those areas with slopes lower than 12%.

The improvements made in the agricultural process will also enhance the quality of the sugarcane received in the sugarmill. For example, mechanical harvested sugarcane will replace the conventional washing by dry-washing, reducing the sugar losses. Improved sugarcane varieties can also help to achieve high sucrose contents. This will be translated into gains on industrial yields. This scenario considers also a modernization of the industrial equipment. The extraction process for example can be improved by introducing diffusers with higher extraction capacity (BNDES and CGEE 2008b; Centro de Gestão e estudios estratégicos 2009).

The progressive implementation of mechanical harvest and the high fibre content of the sugarcane in the NE region, makes the generation of surplus electricity more feasible. The sugarmills need to implement some changes such as the installation of high pressure boilers.

The potential annual growth of efficiency reported by the Energy National Plan for Brazilian plants that can be achieved by including the improvements explained above are 0.56% for distilleries and 0.35% for sugar factories (Verde Leal et al. 2010). For scenario A current average yields for distilleries and sugar factories have been taken which are 80.6 L/ton and 135.5 kg/ton respectively (ESALQ and USP 2009b) and projected for the year 2020 with the same growth rate considered for a Brazilian sugarmill. In this scenario it is assumed that all the sugar and ethanol produced comes from distilleries and from mix sugarmills, thus sugar factories will not exist. This is because currently the majority of the sugarmills are mix sugarmills (57%) and distilleries (34%). Since the sugar factories are only a minority (9% of all sugarmills) the tendency is that they disappear so all production will come from the other types of sugarmills. Thus, scenario A assumes that 60% of the sugarcane produced is processed in mix sugarmills and 40% in distilleries. It will also assume that 59% of all sugarcane produced will be directed for sugar production and 41% for ethanol production, as it is currently being done. In order to process the additional sugarcane produces as a result of the productivity gains, new sugarmills will need to be constructed. The processing capacity of the new sugarmills constructed will be 2,000,000 ton of sugarcane which is larger than the average capacity nowadays of 1,100,100 ton. This will bring along some economic benefits from the scaling. It has been estimated that the construction of 43 new sugarmills will be required to process the additional sugarcane produced by 2020.

6.6.2.3 Scenario B

This scenario is an extension of the previous scenario A and it assumes an expansion of the sugarcane-ethanol sector in suitable areas of the NE region. Potential areas have been identified by using the Agroecological Zoning of the NE of Brazil (ZANE) developed by the Ministry of Agriculture and Supply of Brazil (EMBRAPA 2009).

ZANE combines different types of information such as soils, climate and water resources to identify and quantify the most favourable areas to grow sugarcane. The restrictions imposed by the Zoning are:

- Areas should have a minimum annual rainfall of 1,500 mm
- Areas with hydric shortfall less than 150-200 mm were excluded
- Areas need to have temperatures between 18°C and 28°C
- Areas that do not go below 2°C to avoid the risk of hoar-frost
- Exclusion of areas with inappropriate soil types to grow sugarcane

The following types of areas have been excluded for sugarcane expansion:

- Land with slopes higher than 12%
- Areas with native vegetation, forest, dunes and mangroves
- Environmental protected areas
- Areas with indigenous tribes
- Mining areas
- Areas where crops are cultivated

The sugarcane Zoning is based on maps and data from 2002. Currently Embrapa is developing a newer version with more recent data (“Probio”project). For more information about the methodology used in the Zoning see EMBRAPA solos (2009).

ZANE makes a classification between high, medium and low potential areas taking into account the type of soil of each area. High potential areas include clay soils and can reach productivities higher than 80 ton/ha. Medium potential areas have clay-sandy soils and can achieve productivities from 60 ton/ha to 80 ton/ha. Low potential areas have sandy soils which lower the productivity to 60 ton/ha. This scenario has considered only land identified as high and medium potential to ensure agricultural productivities are high.

ZANE also takes into account the land use of the areas considered. As mentioned before, areas occupied with other crops are excluded so competition with food production is minimized. The potential expansion areas are classified as (1) Extensive livestock land and (2) Livestock/agricultural land. This last one includes areas with a continuous change in their use and that could not been identified clearly as 100% agricultural or 100% livestock land. For scenario B this last group has not been considered as sugarcane potential expansion areas to avoid any possible competition with food crops, thus only extensive livestock areas have been included for the scenario.
According to ZANE the extensive pasture areas with high and medium potential sum a total of 1,2 million hectares and they are located in the provinces of Bahia, Maranhão and Piauí. Most of these areas (approximately 87%) are located in Bahia and Maranhão.

Since the expansion of sugarcane in this scenario takes place in areas where cattle is being fed, it is important to consider the livestock land needed to meet food consumption in 2020. In order to do this, expected population growths in the NE region were taken into account to calculate the amount of pasture land needed to satisfy their food consumption. Information about population growths of the NE region was used from the Brazilian statistical account database (IBGE 2009a). During the last 20 years the population in the NE region grew annually with 1.1%. With this growth rate it can be expected that population will increase from the current 53 million habitants to about 59 million (by 2020). The current land used for livestock production in the NE is nearly 33 million hectares (IBGE 2009c). This is the land use occupied by the current extensive livestock of the NE region, developed over large tracts of land, with cattle loose and without major application of technological resources and financial investments. The livestock sector in Brazil has an average efficiency of 1 heads/ha where the NE is known to have one of the lowest productivities in their livestock production (EMBRAPA 2004). Considering the expected population growths, the land use will need to expand to 36.6 million hectares by 2020. However the same amount of cattle fed in the current extensive system could become much more efficient which is what this scenario has considered.

An intensification of the livestock sector can free up land that could be used for the sugarcane expansion. The following calculations show the amount of land that can be freed up when using a slightly more efficient production system. It is assumed the livestock sector in the NE today has 2 heads/ha which is a number in between the figures given by the average number for Brazil (1 head/ha) and by the livestock areas identified by the ZANE (4 heads/ha). In order to meet the projected food demands explained above, livestock will be intensified from 2 heads/ha to 3 heads/ha. This is a very reasonable intensification and it can still be considered as an extensive production system. Then, the land use needed to meet future food demands in 2020 can be reduced from 36.6 million hectares to 24.4 million hectares freeing up 12.2 million hectares. As it can be seen, the land needed to meet food demand is lower than the current land use for livestock (33 million hectares) and higher than the amount of areas considered in this scenario (1.2 million ha). This means that a slight intensification of the livestock sector will free up enough land to cultivate sugarcane. Note that only food demand in the NE region has been considered in the calculations and not world food demand. It could be assumed that future meat exports can be achieved by intensifying a bit more the livestock sector in the NE region. Besides, the land needed for this could be located in the areas identified as low potential areas for sugarcane expansion and excluded in this scenario which are nearly 1.5 million hectares according to the Agricultural Zoning.

The majority of the areas identified in the province of Bahia are close to the current sugarcane cultivated areas and the port of Salvador which geographically is a good location for international exports. Another port of large depth is planned to be built in the coastal city of Ilhéus, which will be even closer to the sugarcane expansion areas. The areas identified in the state of Maranhão have roads that connect to a large port with sufficient depth to accommodate 400,000 ton capacity boats. The port is currently being modernized to store large quantities of liquids for a future ethanol and biodiesel production (Polo Nacional de Biocombustíveis et al. 2006). A large project ("*ferroviaria transnordestina*") is being carried out in the NE region to construct a railway that will connect the interior areas with the coastal areas of several Northeastern states. This railway will connect the inner part of Piauí (and considered here as sugarcane expansion areas) with the port of São Luis. Moreover, the government, in particular in the state of Maranhão, is willing to develop the sugarcane-ethanol sector and to provide the necessary support to achieve this goal as it is currently being done with the *SINCOEX* program (Jornal Cana 2006; Polo Nacional de Biocombustíveis et al. 2006).

The same technological levels for the agricultural and industrial processes assumed for scenario A are applied to scenario B. The only difference is that the sugarcane production in the expansion areas is presumed to be used for ethanol production so all new plants constructed will be distilleries. It has been estimated that 104 new sugarmills will be required to process the additional sugarcane produced by 2020.

6.6.3 Appendix C: Construction of extended inter regional IO model for case study NE Brazil

C1 Example industry-based approach

In order to describe the theoretical framework of an IO model with mix technologies an example is given here, based on Cunha and Scaramucci (2006). Assuming an economy with the following 7 sectors:
S_1: Manually harvested sugarcane
S_2: Mechanically harvested sugarcane
S_3: Ethanol produced in a sugarmill that produces both ethanol and sugar
S_4: Ethanol produced in distillery
S_5: Total sugarcane
S_6: Total ethanol
S_7: Rest of the economy
The intermediate deliveries between the sectors are expressed with the technical coefficients a_{ij}. The production in sectors S_5 and S_6 are linear which means that the required inputs can be combined in any ratio while all the other sectors are described by the regular Leontief function.

The total sugarcane produced (sector 5) receives its inputs from the manual harvested sugarcane sector (sector 1) and from the mechanical harvested sugarcane sector (sector 2). For those sectors that consume sugarcane (e.g. the ethanol sector) it is not important how the sugarcane was produced. The outputs of sector 1 and 2 can be written as,
$X_1 = \alpha X_5$ (1B)
$X_2 = \beta X_5$ (2B)
where α and β are the contribution of the manual and mechanical harvested sugarcane respectively to the total sugarcane produced. It is clear that:
$\alpha + \beta = 1$ (3B)
$0 < \alpha, \beta < 1$ (4B)
Analogously the total ethanol produced can be written as:
$X_3 = \gamma X_6$ (5B)
$X_2 = \delta X_6$ (6B)
where γ is the contribution of the ethanol produced in a mix sugarmill that produces both ethanol and sugar and δ is the contribution of the ethanol produced in a distillery.
Applying the basic IO principle to the rows corresponding to the sectors S_5, S_6 and S_7.

$$\begin{cases} a_{51} X_1 + a_{52} X_2 + a_{53} X_3 + a_{54} X_4 + a_{57} X_7 + Y_5 = X_5 \\ a_{61} X_1 + a_{62} X_2 + a_{63} X_3 + a_{64} X_4 + a_{67} X_7 + Y_6 = X_6 \\ a_{71} X_1 + a_{72} X_2 + a_{73} X_3 + a_{74} X_4 + a_{77} X_7 + Y_7 = X_7 \end{cases} \qquad (7B)$$

Substituting (1B), (2B), (5B) and (6B) in (7B),

$$\begin{cases} (a_{51}\,\alpha + a_{52}\,\beta)\,X_5 \;+\; (a_{53}\,\gamma + a_{54}\,\delta)\,X_6 \;+\; a_{57}\,X_7 \;+\; Y_5 \;=\; X_5 \\ (a_{61}\,\alpha + a_{62}\,\beta)\,X_5 \;+\; (a_{63}\,\gamma + a_{64}\,\delta)\,X_6 \;+\; a_{67}\,X_7 \;+\; Y_6 \;=\; X_6 \\ (a_{71}\,\alpha + a_{72}\,\beta)\,X_5 \;+\; (a_{73}\,\gamma + a_{74}\,\delta)\,X_6 \;+\; a_{77}\,X_7 \;+\; Y_7 \;=\; X_7 \end{cases} \qquad (8B)$$

Typically in an IO model Y_5, Y_6 and Y_7 are exogenous variables and X_5, X_6 and X_7 are endogenous variables. The equation's system of (8B) is similar to the conditions of the basic IO model (equation 3):

$AX + Y = X$ (3)

where $A = \begin{Bmatrix} (a_{51}\,\alpha + a_{52}\,\beta) & (a_{53}\,\gamma + a_{54}\,\delta) & a_{57} \\ (a_{61}\,\alpha + a_{62}\,\beta) & (a_{63}\,\gamma + a_{64}\,\delta) & a_{67} \\ (a_{71}\,\alpha + a_{72}\,\beta) & (a_{73}\,\gamma + a_{74}\,\delta) & a_{77} \end{Bmatrix}$, $X = \begin{Bmatrix} X_5 \\ X_6 \\ X_7 \end{Bmatrix}$, $Y = \begin{Bmatrix} Y_5 \\ Y_6 \\ Y_7 \end{Bmatrix}$

The solution of the extended IO model is found in the same way as the basic IO model, (equation 4)

C 2 Example commodity-based and industry-based approach

Assumed is that sugar and ethanol are produced in a given economy by the following technologies:
T_1: Technology that produces ethanol and sugar simultaneously (mix sugarmill)
T_2: Technology that produces only-ethanol (distillery)
In the first technology, the *commodity-based approach* is applied (Table 6C-11), one part of the production of this sector is directed to the production of ethanol ($\beta_{1,3}$) and the other part will be directed to the production of sugar ($\beta_{1,4}$). The total output (X_1) of technology 1 (T_1) will be given by:

$X_1 = \beta_{1,3} + \beta_{1,4}$ (9B)

where $\beta_{1,3} + \beta_{1,4} = 1$ and $0 < \beta_{1,3}, \beta_{1,4} < 1$
The industry-based approach is applied for the total amount of ethanol produced (X_3) that will come from the ethanol produced in a mix sugarmill ($\beta_{1,4}\,X_1$) and that generated in a distillery ($\alpha_{2,3}\,X_2$) as explained earlier.

Table 6C-11: Matrix and equations used under the industry-based technology approach and commodity-based technology approach for a two-technology example

		1	2	3	4
		T_1	T_2	Total ethanol	Total sugar
1	T_1	$\beta_{1,3}\,X_1$	$\beta_{1,4}\,X_1$		
2	T_2	$\alpha_{2,3}\,X_2$			
3	Total ethanol			$X_3 = \beta_{1,3}\,X_1 + \alpha_{2,3}\,X_2$	
4	Total sugar				$X_4 = \beta_{1,4}\,X_1$

When considering all the agricultural and industrial technologies that can take place in the scenarios studied a total number of 15 new technologies are obtained. These technologies are responsible for the production of five different commodities which are sugarcane, ethanol, sugar, electricity and livestock. The technologies can be combined in each scenario. For example, the BaU scenario in 2020 assumes that there will be 50% of mechanical harvested sugarcane and 50% of the manual harvested sugarcane and therefore, according to the technologies presented in Table 6-5, there will be 50% of the technology “Sc_Man 20” and 50% of the technology “Sc_Mec 20”.

C3 Sector aggregation

Table 6C-12: Sector aggregation in extended inter-regional IO model

Sector #	Sector name in the extended IO model	Guilhoto et al. (2010)sector #
1	Animal production	3
2	Sugarcane	1
3	Ethanol	15
4	Sugar production	6
5	Electricity production	40, 41
6	Other crops	2
7	Fuels extraction and mining	4, 5
8	Food, tobacco, textile and footwear	7, 8, 9, 10
9	Wood products and others (books, Cds)	11, 13, 39
10	Paper and office equipment	12, 31
11	Coke and refined petroleum products	14
12	Fertilizers and other chemical products	16
13	Resine, plastic and rubber products	17, 23
14	Pharmaceutical, cleaning and veterinary products	18, 20
15	Agrochemicals	19, 21
16	Paints, varnishes and other chemical products	22
17	Cement, concrete, glass and keramic products	24
18	Mineral products (non-metalic)	25
19	Steel and metal products	26, 27, 28
20	Machines and equipments	29
21	Domestic and hospital appliances	30, 34
22	Electrical machines and equipment	32, 33
23	Motor vehicles (automobiles, trucks and buses)	35, 36
24	Accessories for vehicles	37, 38
25	Water and gas supply	43
26	Construction	44
27	Electricity transmission and distribution	42
28	Commerce	45, 46, 47, 48, 49, 50
29	Transport , storage and post	51
30	Services to companies	52, 57
31	Finance and insurance	53
32	Accomodation and food services	54, 56
33	Repair and maintenance	55
34	Education, health and public administration	58, 59, 60, 61, 62, 63

C4 Simplified structure of the extended inter-regional IO model that is used in this study

Table 6C-13: Structure of the extended inter-regional IO model that is used in this study

		Traditional areas NE		Expansion areas NE		Rest of Brazil	Final demand			Total production output		
		Technologies	IO sectors	Technologies	IO sectors	IO sectors						
		Sc_Man 10 … (Et+Sug+El)20	S_1 S_{34}	Sc_Man 10 … (Et+Sug+El)20	S_1 S_{34}	S_1 S_{34}	Y_{TRAD}	Y_{EXP}	$Y_{rest\ Br}$	X_{TRAD}	X_{EXP}	$X_{rest\ Br}$
Traditional areas NE	1 … 15											
	16 … 50											
Expansion areas NE	51 … 66											
	67 … 101											
Rest of Brazil	102 … 136											
	Imports Taxes Labour Kapital X^T											

6.6.4 Appendix D: Input data

The cost data in the study of ESALQ (2009) is given for two types of sugarcane production systems (sugarmills and outgrowers). Since the production costs for outgrowers and for sugarmills were not very different, this study has calculated one single production cost for the NE region to simplify the calculations in the extended IO model. From the two production costs, the weighted average was calculated considering that 70% of the total sugarcane of the NE is produced by sugarmills and 30% comes from outgrowers see Table 6D-14 below.

Table 6D-14: Cost items of sugarcane production in NE Brazil adapted from (ESALQ and USP 2009a)

SUGARCANE PRODUCTION COSTS	$US\$_{2010}$/ton[a]		$US\$_{2010}$/ton
Soil preparation and planting	5.5	*Administration*	5.7
Mechanized operations	0.9	Owner/manager remuneration[b]	0.5
Labour	1.3	Administration costs	5.2
Inputs	3.3	*Depreciation*	1.8
Fertilizers, agrochemicals application and others	9.3	Facilities[c]	0.5
Mechanized operations	1.6	Irrigation/ferti-irrigation	0.4
Labour	1.3	Machines	0.9
Inputs	6.4	*Capital remuneration*	2.0
Harvest	8.7	Machines	1.2
Mechanized operations	2.2	Facilities[c]	0.0
Labour	6.5	Working capital/interest	0.4
Transport of sugarcane	3.4	Agricultural tillage system	0.3
Land remuneration	3.6	Irrigation/ferti-irrigation	0.1
Own land	2.2		
Land leasing	1.4		
Total agricultural cost ($US\$_{2010}$/ton)		40.0	

[a] The monetary values in ESALQ (2009a; 2009b) are converted from Brazilian real ($R\$_{2008}$) to $US\$_{2010}$ using the inflation rate between 2008 and 2010 in Brazil of 15% and the exchange rate of 2010; 1US$=1.7594 R$ (Ipeadata 2010b; Ipeadata 2010a). Furthermore, it is assumed that no significant changes in costs have occurred other than inflation.
[b] Only applicable to outgrowers with a high number of self-employeed workers
[c] These include offices, house for staff, grids for electricity, dams, machine shed and water treatment station

It was necessary to further disaggregate the production costs of Table 6D-14 in order to allocate each cost to the corresponding sectors of the initial IO table (e.g. the cost of mechanized operations had to be further divided in fuel cost and repair and maintenance cost). This additional disaggregation of the costs was applied for the mechanized operation costs, the agricultural inputs used and the administration costs by using additional literature and estimates of experts at CTBE (IBGE 2008). The contribution of each component item to these costs is given in the tables below. The costs of repair and maintenance (R&M) for the mechanized operations were further disaggregated. This was done for all those processes that include mechanized operations (soil preparation and planting, the application of fertilizers and agrochemicals, irrigation, harvesting and the transport of sugarcane) and also for the R&M of facilities (e.g. offices, house for staff, grids for electricity, dams, machine sheds and the water treatment station) which were included in the total administrative costs. In order to translate the costs expenditures of R&M into the different sectors of the IO table, all IO sectors that could potentially contribute to these costs were considered. Table 6D-25 shows the individual contribution of each expense to the total R&M costs of the operations involved during the production of sugarcane, sugar and ethanol.

The cost data related to the harvest of sugarcane is given in Table 6D-15, and data related to the irrigation systems considered in the scenarios A and B in Table 6D-16. The benefits accompanying the use of irrigation were also included in the cost data used. The use of irrigation increases the longevity of the crop which reduces the implementation costs looking over the lifetime of the sugarcane, see Table 6D-17 (Bernardo 2006). On the other hand, higher yields are obtained and thus, as a consequence, other costs will increase (e.g. fertilization costs, harvest costs, transport costs). Although some of these increases can be considered proportional to the growth in yields, in the case of the use of fertilizers the increase is not necessarily proportional. This is because of the high efficiency in fertilizer's application when using ferti-irrigation systems. Considering all these effects, the modifications introduced in the costs for irrigated areas were estimated.

Table 6D-15: Data related to sugarcane harvesting

	Value	Data source
Diesel consumption manual harvest (L/ha/yr)	167	(de Figuereido 2011)
Diesel consumption mechanical harvest (L/ha/yr)	243	(de Figuereido 2011)
Investment conventional harvest machine ($US\$_{2010}$)	540,747	(ESALQ 2009a, 2009b)
Investment advance harvest machine ($US\$_{2010}$)[a]	811,120	(expert, fieldwork)
Discount rate (%)	15%	(expert, fieldwork)
Useful life (years)	10	(expert, fieldwork)
Annual payment conventional harvest machine ($US\$_{2010}$)	107,745	[b]
Annual payment advanced harvest machine ($US\$_{2010}$)	161,617	[b]
Productivity conventional harvest machine (ton/day)	800	(expert, fieldwork)
Productivity advance harvest machine (ton/day)	1000	(expert, fieldwork)
Working time of harvest machine (days/yr)	150	(Ramos, 2007)
Working time sugarcane cutter (days/yr)	180	(Ramos, 2007)
Number of employees needed per harvest machine	6	(sugarmills, fieldwork)

[a] Harvest machine able to work on slopes > 12%
[b] Annual payment was calculated as: A= (P $(1+r)^n$)/($(1+r)^n$-1) where P is the loan amount (investment), *r* the discount rate and *n* the total number of payments (useful life)

Table 6D-16: Data related to sugarcane irritation, considered in scenarios A and B

Irrigation	Drip-	Pivot-	Data source

	irrigation	irrigation	
	Value	Value	
Implementation costs (US$$_{2010}$/ha)	4,064	2,687	(sugarmill, fieldwork)
Useful life (years)	10	10	(ESALQ 2009a, 2009b)
Discount rate (%)	15%	15%	(expert, fieldwork)
Salvage value (%)	0	0	(ESALQ 2009a, 2009b)
Annual payment (US$$_{2010}$/ha)	810	535	[a]
Operational costs (US$$_{2010}$/ha)	1,274	583	(sugarmill, fieldwork)
Electric energy	140	186	(sugarmill, fieldwork)
Repair and maintenance	739	245	(sugarmill, fieldwork)
Labour	395	152	(sugarmill, fieldwork)
Water used (mm/yr)	560	300	(sugarmill, fieldwork)
Electricty price (US$$_{2010}$/Mwh)	48	48	(Epe, 209; Gilhoto 2010)
Water storage system			
Investment dam of 57,000 m^3 (US$$_{2010}$/unit)	9,831,761		(sugarmill, fieldwork)
Discount rate (%)	15%		(expert, fieldwork)
Useful life (years)	25		(ESALQ 2009a, 2009b)
Salvage value (%)	10%		(ESALQ 2009a, 2009b)
Annual payment (US$$_{2010}$/unit)	1,520,968		[a]
Annual rainfall in the coastal region of the NE (mm)	1500		(Duke Energy Brasil 2011)

[a] Annual payment was calculated as: $A= (P\ (1+r)^n)/((1+r)^n-1)$ where P is the loan amount (investment), *r* the discount rate and *n* the total amount of payments (useful life)

Table 6D-17: Change in cost and crop lifetime for technologies related to irrigation

Annual cost change ferti-irrigation system[a]		Data source
Seedling	45%	(Machado 2002)
Implementation	45%	(Machado 2002)
Fertilization and other chemical application	45%	(Machado 2002)
Agricultural inputs	101%	(expert, fieldwork)
Lifetime crop		
Irrigated system (yr)	11	(expert, fieldwork)
Non-irrigated system (yr)	5	(Machado 2002)

[a] When costs change < 100% means cost reduction from the non-irrigated system and when the change is > 100% means costs increase

To include the benefits from the use of improved sugarcane species, it was assumed that the large and medium sugarcane producers (responsible for 35% of total sugarcane produced) help financing the necessary R&D programs to develop new species, which is common practise. Currently R&D programs are partly financed by the private sector and partly by public funds (Hasegawa 2005). It was assumed that 1% of the total production costs were earmarked for R&D programs to develop better sugarcane varieties.

The total sugarcane production costs are assumed to remain unchanged over time and thus, the cost of 40 US$$_{2010}$ per tonne (Table 6D-14) will be the same for all scenarios. It is assumed that although the productivity gains reduce the production costs, the price difference, or profits, will be re-invested in capital.

Taking the costs of the livestock sector in 2010 as a reference, two assumptions are made to include a semi-intensification of the livestock in the extended IO model (i) animal feed will increase proportionally to the intensification that takes place, leading to 50% increased costs for the semi-intensified system (ii) labour costs will increase with 10% compared with the reference livestock technology.

The same procedure that is used to calculate the technical coefficients for the agricultural production system, has been applied for the industrial technologies. Based on a series of parameters that define a typical sugarmill in the NE region (see Table 6D-18), ESALQ (2009a; 2009b) has calculated the industrial production costs (see Table 6D-19). The production costs per ton sugarcane were used for a sugarmill producing both sugar and ethanol while the production costs per tonne of sugar and ethanol were used for factories producing only sugar and producing only ethanol respectively.

Table 6D-18: Assumptions adopted in the industrial cost calculation of NE Brazil by ESALQ (2009a; ESALQ and USP 2009b)

	Unit	Value		Unit	Value
Quality of the sugarcane			Productivity		
Pol (sucrose content)	%	14	*Hours for milling per year*	h	3,628
Fibre content	%	13	*Hours without production per year*	h	1,041
Purity of sugarcane juice	%	84	*Efficiency*	%	78
Total reducing sugars	Kg/ton	160	Production mix		
Industrial yields			*% of sugarcane for sugar production*	%	64
Cane washing	%	90	*% of sugarcane for ethanol production*	%	36
Industrial losses	%	11	Production of by-products		
Fermentation efficieny	%	85	*Bagasse*	kg/ton	304
Destilation efficieny	%	99	*Filter cake*	kg/ton	33
Molasses purity	%	45	*Vinasse*	L/L	15
Milling capacity sugarmill	Mton	1.1	Electricity production	MWh	31,812
Production of sugar and ethanol					
White sugar	%	55			
Hydrated ethanol	%	42			

Table 6D-19: Cost items of sugar and ethanol production in NE Brazil, based on ESALQ (2009a; 2009b)

INDUSTRIAL PRODUCTION COSTS	US$$_{2010}$/ton	US$$_{2010}$/ts	US$$_{2010}$/m^3
Sugarcane costs	36.1	266.3	448.0
Operational costs	32.6	240.7	404.5
Sugarcane from outgrowers	30.8	79.9	132.2
Sugarcane from the sugarmills	33.6	160.8	272.3
Depreciations	1.2	8.6	14.6
Opportunity costs of land and capital	2.3	17.1	28.9
Industrial costs	13.1	100.4	150.7
Industrial operations	6.5	48.5	77.5

Labour	2.2	16.5	28.0
Industrial inputs	1.5	12.2	15.9
Chemical	0.8	5.3	12.1
Electrodes	0.1	0.5	0.9
Lubrificant and fuels	0.1	0.8	1.3
Electricity	0.1	1.0	1.6
Packing	0.4	4.7	0.0
Maintenance[a]	2.7	19.8	33.5
Material	1.9	14.2	24.1
Services	0.8	5.5	9.4
Industrial depreciation	2.4	18.5	26.2
Industrial capital costs	4.3	33.4	47.1
Administration costs	4.5	33.4	56.6
Labour	1.7	12.7	21.5
Inputs and services	2.1	15.7	26.5
Working capital	0.7	5.1	8.6
Total industrial cost	53.7	400.2	655.4

[a] Maintenance includes: repair of motors, pumps, electrical installations, valves, painting and cleaning

Since scenarios A and B include technologies that use more efficient industrial equipment and that are capable to generate surplus electricity, additional information is needed which is provided in Table 6D-20 and Table 6D-21.

Table 6D-20: Parameters for sugarmills that use conventional and progressive technologies based on (ESALQ and USP 2009a; ESALQ and USP 2009b; UNICA 2010) and interviews

CONVENTIONAL SUGARMILL	Distillery	Sugar factory	Mix sugarmill
Capacity (Mton)	1.1	1.1	1.1
Investment (US$$_{2010}$/ton)	66	79	74
Equipments	39	47	44
Electromechanical set-up	5	6	5
Construction	9	10	10
Electrical instalations	5	6	6
Instruments/automation	1	2	1
Services of engineering, thermal insulation and painting	7	8	7
PROGRESSIVE SUGARMILL			
Capacity (Mton)	2	NA[a]	2
Investment US$$_{2010}$/ton)	110	NA[a]	120
Equipments	57	NA[a]	63
Electromechanical set-up	7	NA[a]	7
Construction	12	NA[a]	14
Electrical instalations	8	NA[a]	8
Instruments/automation	2	NA[a]	2
Services of engineering, thermal insulation and painting	9	NA[a]	10
Equipment for the production of surplus electricity	16	NA[a]	16
Pressure boiler (bar)	43	NA[a]	43
Surplus electricity generated (KWh/ton)	49	NA[a]	46

[a] Means not applicable (this analysis excluded sugarmills where only sugar is produced in the progressive scenarios (A+B).

Table 6D-21: Contribution of the different items to the total equipment costs (ESALQ and USP 2009a; ESALQ and USP 2009b; UNICA 2010)

Components of equipment	Distillery	Sugar factory	Mix sugarmill
Steam generator	20%	25%	23%
Reception and extraction system	25%	20%	22%
Destillery	30%	15%	20%
Sugar processor	0%	15%	10%
Turbine/power generator	10%	10%	10%
Others	15%	15%	15%

Table 6D-22 shows the data that was used to calculate the average salaries paid to employees in the studied scenarios. A large difference in labour costs between the scenarios occurs due to the change from manual harvesting to mechanized harvesting. The use of irrigation (and the consequent need of more specialized labour) is assumed not to change the total labour costs from the reference case significantly. It is assumed that employers have to pay 27% of the wage on additional expenditures to pay the social security funds of the employees.

Table 6D-22: Data related to employment used in the IO analysis

Data related to employees[a] in the sugarcane sector			
Type of employment	Salary ($US\$_{2010}$/month)		
Low qualified employee	317		
Medium qualified employee	475		
High qualified employee	633		
	Contribution to labour costs[b]		
Planting and application of agricultural inputs	24% - 52%		
Harvest	59% - 9%		
Administration and management	18% - 39%		
Data related to employees in a distillery[c]			
	Salary ($US\$_{2010}$/month)	Number of employees	Contribution to labour costs
Low qualified employee	338	178	41%
Technician	455	59	19%
Administration employee	568	32	13%
Coordinator	1,137	13	10%
Responsible for the department	3,410	5	12%
Manager	7,957	1	5%

[a] (sugarmills and experts, fieldwork)
[b] Calculated with data from (ESALQ and USP 2009a; ESALQ and USP 2009b). The first number in the range given applies when 100% manual harvest is done and the second number is when 100% mechanical harvest is done
[c] (ESALQ and USP 2009a; ESALQ and USP 2009b)

Allocation of the input data to the IO sectors in the model

The different technical coefficients of the different items involved in the sugarcane-ethanol-sugar production were allocated into the corresponding sector of the extended IO model. Table 6D-23 illustrates the assignment of the production cost items to the IO sectors in which they are produced. In the IBGE database (2005a) a detailed specification is given of all the items contained in the IO sector which facilitates the allocation of the different cost items to the IO sectors.

Table 6D-23: Cost items during production and processing of sugarcane and their associated sectors in the IO table

Costs items	IO Sector name	IO sector number
Mechanical operations		
Diesel and lubricants	Coke and refined petroleum products	11
Repair and maintenance		
Resine, plastic and rubber products	Resine, plastic and rubber products	13
Steel and metal products	Steel and metal products	19
Electrical machines and equipment	Electrical machines and equipment	22
Accessories for vehicles	Accessories for vehicles	24
Hired repair and maintenance services	Repair and maintenance services	33
Agricultural inputs		
Fertilizers	Fertilizers and other chemical products	12
Lime and plaster	Mineral products (non-metalic)	18
Agrochemicals	Agrochemicals	15
Seeds	Sugarcane	2
Maturator, dissicant	Fertilizers and other chemical products	12
Industrial inputs		
Sugarcane	Sugarcane	2
Chemical	Paints, varnishes and industrial chemical products	16
Electrodes	Electrical machines and equipment	22
Lubrificant and fuels	Coke and refined petroleum products	11
Electricity	Electricity production	5
Packing	Resine, plastic and rubber products	13
Irrigation equipment		
Electric energy equipment	Electrical machines and equipment	22
Administration		
Finance and insurance	Finance and insurance	31
Water and gas	Water and gas supply	25
Services to companies	Services to companies	30
Accomodation and food services	Accomodation and food services	32
Office material	Paper and office equipment	10
R&D for new sugarcane species	Services to companies	30
Labour	Labour	
Owner/manager remuneration	Labour	
Land remuneration	Capital	
Depreciation	Capital	
Capital remuneration	Capital	

Table 6D-24: Contribution of the different cost items to the total mechanization costs, agricultural inputs and administration costs

Costs items	Contribution of each item[a]	Data source
Mechanization costs		
Fuels	48%	(Experts, field work)
Lubrificants	8%	(Experts, field work)
Repair and maintence of equipment	45%	(Experts, field work)
Agricultural inputs costs		
Fertilizers	53%	(Experts, field work)
Lime and plaster	7%	(Experts, field work)
Agrochemicals	16%	(Experts, field work)
Seeds	21%	(Experts, field work)
Other chemical products (maturator, dissicant)	3%	(Experts, field work)
Administration costs		
Repair and maintenance of facilities	35%	(IBGE 2008)
Finance and insurance	32%	(IBGE 2008)
Water and gas	20%	(IBGE 2008)
Services to companies	8%	(IBGE 2008)
Accomodation and food services	3%	(IBGE 2008)
Office material	2%	(IBGE 2008)

[a] Note that the sum of the individual contributions can be slightly higher than 100% due to the number's rounding

Table 6D-25: Contribution of the different cost items to repair and maintenance costs

Items R&M	In planting, chemical application and harvesting	In transport equipment	In irrigation equipment	R&M of facilities	Data source
Resine, plastic and rubber products	39%	-	30%	28%	(IBGE 2008, expert field work)
Steel and metal products	53%	30%	15%	40%	(IBGE 2008, expert field work)
Electrical machines and equipment	3%	8%	53%	30%	(IBGE 2008, expert field work)
Accessories for vehicles	3%	60%	-	-	(IBGE 2008, expert field work)
Hired R&M services	2%	2%	2%	2%	(IBGE 2008, expert field work)

Table 6D-26: Technical coefficients calculated for the different agricultural and livestock technologies introduced in the extended IO model

	Livestock technologies		Agricultural technologies					
IO sector number	Lvst (2 heads/ha)	Lvst Tec (3 heads/ha)	Sc_Man 10	Sc_Mec 10	Sc_Man 20	Sc_Mec 20	Sc_Man Tec 20	Sc_Mec Tec 20
1	0.048	0.042	0.000	0.000	0.000	0.000	0.000	0.000
2	0.000	0.000	0.050	0.050	0.046	0.046	0.043	0.043
3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	0.006	0.005	0.000	0.000	0.000	0.000	0.016	0.016
6	0.053	0.047	0.000	0.000	0.000	0.000	0.000	0.000
7	0.007	0.007	0.000	0.000	0.000	0.000	0.000	0.000
8	0.126	0.168	0.000	0.000	0.000	0.000	0.000	0.000
9	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
10	0.000	0.000	0.001	0.001	0.001	0.001	0.001	0.001
11	0.016	0.014	0.105	0.135	0.096	0.123	0.096	0.122
12	0.012	0.011	0.135	0.135	0.124	0.124	0.116	0.116
13	0.001	0.001	0.029	0.038	0.026	0.035	0.033	0.041
14	0.015	0.013	0.000	0.000	0.000	0.000	0.000	0.000
15	0.004	0.003	0.040	0.040	0.036	0.036	0.034	0.034
16	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
17	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
18	0.000	0.000	0.017	0.017	0.016	0.016	0.015	0.015
19	0.001	0.001	0.053	0.066	0.049	0.060	0.050	0.061
20	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
21	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
22	0.000	0.000	0.014	0.015	0.013	0.013	0.029	0.029
23	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
24	0.000	0.000	0.028	0.029	0.026	0.027	0.028	0.029
25	0.000	0.000	0.017	0.017	0.016	0.016	0.010	0.010
26	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
27	0.035	0.031	0.000	0.000	0.000	0.000	0.000	0.000
28	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000
29	0.009	0.008	0.000	0.000	0.000	0.000	0.000	0.000
30	0.003	0.003	0.007	0.007	0.006	0.006	0.006	0.006
31	0.007	0.007	0.028	0.028	0.025	0.025	0.016	0.016
32	0.000	0.000	0.003	0.003	0.002	0.002	0.002	0.002
33	0.000	0.000	0.002	0.003	0.002	0.003	0.003	0.003
34	0.002	0.002	0.000	0.000	0.000	0.000	0.000	0.000
Labour	0.606	0.592	0.284	0.128	0.259	0.117	0.264	0.113
Capital	0.047	0.044	0.185	0.287	0.255	0.349	0.238	0.343

Lvst Tec: Livestock production intensified (3 heads/ha)
Sc_Man 10: Agricultural technology in 2010 with 100% manual harvest
Sc_Mec 10: Agricultural technology in 2010 with 100% mechanical harvest
Sc_Man 20: Agricultural technology in 2020 with 100% manual harvest
Sc_Mec 20: Agricultural technology in 2020 with 100% mechanical harvest
Sc_ManTec 20: Agricultural technology in 2020 with 100% manual harvest and higher technological levels (e.g. irrigation, better sugarcane varieties)
Sc_MecTec 20: Agricultural technology in 2020 with 100% mechanical harvest and higher technological levels (e.g. irrigation, better sugarcane varieties)

Table 6D-27: Technical coefficients calculated for the different industrial technologies introduced in the extended IO model

	Industrial technologies							
IO sector number	Et10	Et20	Sug10	Sug20	(Et+Sug)10	(Et+Sug)20	(E+El) 20	(Et+Sug+El)20
1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	0.684	0.684	0.666	0.666	0.672	0.672	0.591	0.592
3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
6	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
7	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
8	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
9	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
10	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
11	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
12	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
13	0.016	0.016	0.027	0.027	0.023	0.023	0.013	0.020
14	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
15	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
16	0.018	0.018	0.013	0.013	0.015	0.015	0.016	0.013
17	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
18	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
19	0.021	0.021	0.021	0.021	0.021	0.021	0.018	0.018
20	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
21	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
22	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
23	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
24	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
25	0.004	0.004	0.004	0.004	0.004	0.004	0.003	0.003
26	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
27	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
28	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
29	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
30	0.012	0.012	0.012	0.012	0.012	0.012	0.011	0.011
31	0.020	0.020	0.020	0.020	0.020	0.020	0.018	0.018
32	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
33	0.014	0.014	0.014	0.014	0.014	0.014	0.012	0.012
34	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Labour	0.076	0.076	0.073	0.073	0.074	0.074	0.065	0.065
Capital	0.125	0.125	0.142	0.142	0.136	0.136	0.244	0.239

Et10: Technology in 2010 in the distilleries
Et20: BaU technology in the distilleries in 2020
Sug10: Technology in 2010 in the sugarmills producing sugar
Sug20: BaU technology in the sugar factories in 2020
(Et+Sug)10: Technology in 2010 in the mixed sugarmills
(Et+Sug)20: BaU technology in the mixed sugarmills in 2020
(Et+El)20: Technological improvement for distilleries in 2020 (e.g. surplus electricity produced, more efficient equipment)
(Et+Sug+El)20: Technological improvement for mixed sugarmills in 2020 (e.g. surplus electricity produced, more efficient equipment)

6.6.5 Appendix E: Detailed output results

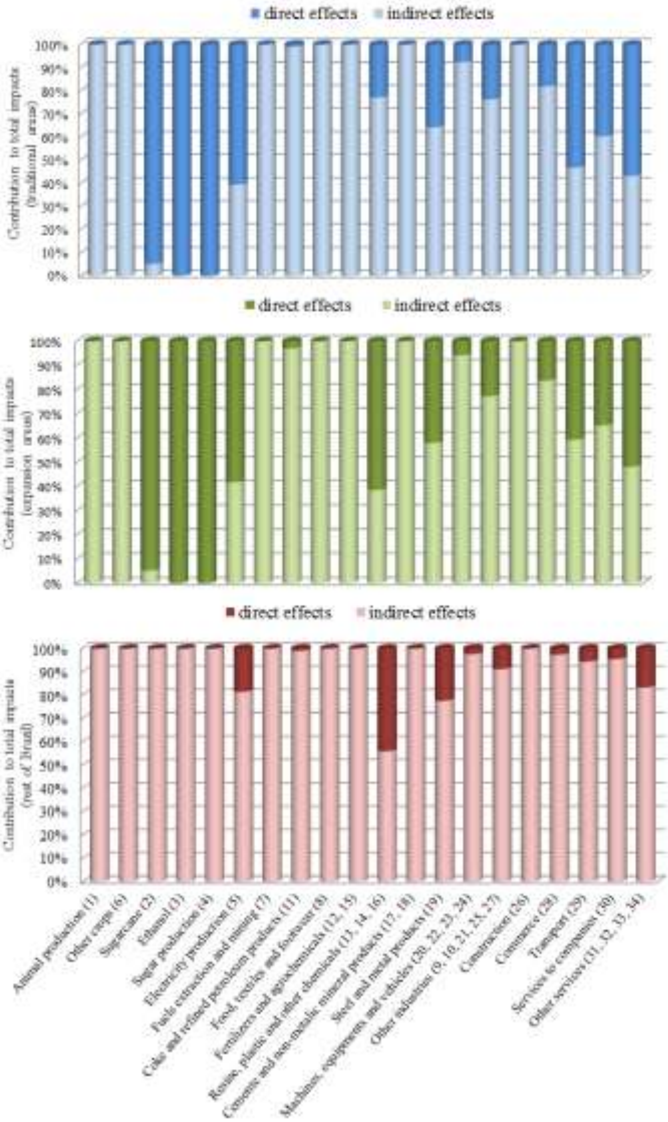


Figure 6E-7: Contribution of direct and indirect effects on the GDP for all sectors in the traditional and expansion areas of NE Brazil and in the rest of Brazil

Results are only presented for Value added and for the BaU scenario because all other scenarios lead to similar results. In order to facilitate the presentation of the results in the figure some sectors have been aggregated.

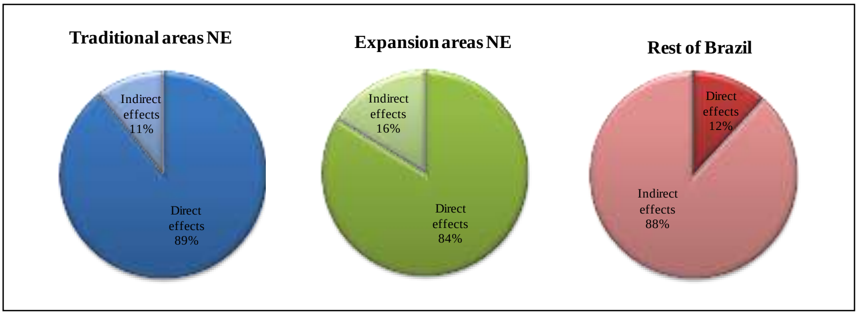


Figure 6E-8: Contribution of direct and indirect effects to the total impact observed for GDP in the three studied regions in a simulation where the traditional and expansion areas of NE are identical in terms of production

Table 6E-28: changes in total output for the three scenarios studied, including the reference scenario

Sector name (#)[23]	X (million US$$_{2010}$)					
	Reference scenario			BaU scenario		
	Trad NE	Exp NE	ROB	Trad NE	Exp NE	ROB
Animal production (1)	0.1	0.2	1.5	0.1	0.2	1.5
Other crops (6)	0.2	1.0	5.1	0.2	1.0	5.4
Sugarcane (2)	1,462	345	5	1,592	376	4.9
Ethanol (3)	1,286	430	9	1,408	471	9.8
Sugar production (4)	1,407	182	1	1,542	200	1.2
Electricity production (5)	3.3	7.3	10.9	3.5	7.9	11.6
Fuels extraction and mining (7)	2.3	19.1	90.9	2.3	20.5	97.6
Coke and refined petroleum products (11)	2.5	44.1	156.8	2.7	47.7	170.1
Food, textiles and footwear (8)	2.2	1.5	8.9	2.3	1.6	9.4
Fertilizers and agrochemicals (12, 15)	11.7	94.3	212.8	11.6	94.6	213.8
Resine, plastic and other chemicals (13, 14, 16)	5.2	18.7	190.0	5.6	20.4	207.4
Cemente and non-metalic mineral products (17, 18)	6.1	2.6	19.7	6.0	2.6	19.7
Steel and metal products (19)	26.2	17.2	145.4	28.6	18.7	157.1
Machines, equipments and vehicles (20, 22, 23, 24)	3.1	5.7	105.2	3.2	5.8	107.7
Other industries (9, 10, 21, 25, 27)	41.8	17.8	69.1	43.1	18.4	72.8
Construction (26)	1.4	0.9	3.1	1.5	1.0	3.3
Commerce (28)	72.7	27.1	48.1	77.4	28.7	50.5
Transport (29)	42.3	18.8	46.6	45.5	20.0	49.4
Services to companies (30)	65.3	25.1	56.7	69.5	26.5	59.9
Other services (31, 32, 33, 34)	162.5	50.4	71.6	172.3	53.1	75.6
Total	4,603	1,309	1,258	5,018	1,416	1,329

Sector name (#)23	X (million US$$_{2010}$)

[23] Due to the large amount of data some sectors have been grouped

	Scenario A			Scenario B		
	Trad NE	Exp NE	ROB	Trad NE	Exp NE	ROB
Animal production (1)	0.2	0.3	1.9	0.3	0.8	4.4
Other crops (6)	0.3	1.3	6.9	0.6	4.0	15.6
Ethanol (3)	2,188	619	12	2,188	6,844	30
Sugar production (4)	1,591	257	1	1,591	264	3
Electricity production (5)	29.3	16.4	19.0	31.1	81.3	40.5
Fuels extraction and mining (7)	2.6	21.8	114.5	5.0	71.0	276.9
Coke and refined petroleum products (11)	3.2	58.6	210.6	3.2	271.7	419.3
Food, textiles and footwear (8)	2.8	2.0	11.6	4.2	7.3	26.9
Fertilizers and agrochemicals (12, 15)	13.6	113.7	257.0	19.1	434.2	466.3
Resine, plastic and other chemicals (13, 14, 16)	7.6	29.6	289.7	15.4	121.2	608.6
Cemente and non-metalic mineral products (17, 18)	7.1	3.0	23.5	13.0	13.9	54.2
Steel and metal products (19)	38.9	25.9	207.3	59.0	147.9	447.3
Machines, equipments and vehicles (20, 22, 23, 24)	5.3	9.1	159.5	10.5	52.6	355.7
Other industries (9, 10, 21, 25, 27)	46.0	21.4	92.2	52.8	118.0	202.7
Construction (26)	1.7	1.2	4.2	1.9	5.8	9.2
Commerce (28)	98.9	37.4	65.6	103.5	251.6	133.7
Transport (29)	59.5	26.6	63.1	63.1	157.3	132.3
Services to companies (30)	79.5	33.1	75.6	83.2	200.3	153.0
Other services (31, 32, 33, 34)	207.5	68.1	94.6	214.3	455.2	180.9
Total	4,382	1,345	1,710	4,459	9,502	3,560

ROB=rest of brazil

Table 6E-29: Impacts of investments on GDP and employment for each scenario

	Impacts on GDP (million US$$_{2010}$)			Impacts on employment (number of jobs)		
	BaU scenario	A scenario	B scenario	BaU scenario	A scenario	B scenario
Machines and equipments						
Traditional areas NE	0.21	1.03	4.12	14	69	278
Expansion areas NE	0.88	4.26	17.07	39	190	762
Rest of Brazil NE	39	187	749	1,239	5,999	24,017
Electrical machines and equipment						
Traditional areas NE	0.01	0.38	1.18	1	26	79
Expansion areas NE	0.04	1.15	1.40	2	65	200
Rest of Brazil NE	1.9	58	179	61	1,868	5,745
Motor vehicles						
Traditional areas NE	0.02	0.07	0.43	1	5	34
Expansion areas NE	0.06	0.22	0.22	4	14	89
Rest of Brazil NE	2.9	11	69	98	369	2,344
Construction						
Traditional areas NE	0.02	0.21	0.73	1	15	51
Expansion areas NE	0.04	0.53	1.86	2	28	99
Rest of Brazil NE	3.41	41	144	218	2,613	9,208
TOTAL impact (all regions)	48	305	1,168	1,681	11,261	42,906

Table 6E-30: Total investments required to obtain the additional production of sugarcane in the three scenarios in the NE

Capital items in the investments needed	BaU		A		B	
	Traditional areas NE	Expansion areas NE	Traditional areas NE	Expansion areas NE	Traditional areas NE	Expansion areas NE
Machines and equipments	508	121	2,458	585	2,458	9,725
Electrical equipment	27	6	846	182	1,034	2,126
Vehicles[a]	24	6	92	22	92	629
Construction	102	23	1,215	280	1,196	4,074
Total investments (million US$$_{2010}$)	661	156	4,611	1,068	4,780	16,553

[a] Includes automobiles, trucks and buses

Table 6E-31: Average monthly salaries paid to employees in each sector in reference scenario and scenario A

	Average wages (US$ $_{2010}$/month)					
	Reference scenario			Scenario A		
Sector name (#)	Traditional areas NE	Expansion areas NE	Rest of Brazil	Traditional areas NE	Expansion areas NE	Rest of Brazil
Animal production (1)	126	142	308	126	142	308
Other crops (6)	58	135	255	58	308	255
Sugarcane (2)	330	329	362	340	135	362
Ethanol (3)	597	609	786	599	255	786
Sugar production (4)	553	561	663	561	561	663
Electricity production (5)	2,972	2,735	3,622	3,067	2,823	3,622
Fuels extraction and mining (7)	302	1,164	1,602	302	1,164	1,602
Coke and refined petroleum products (11)	5,577	6,550	5,920	5,577	6,550	5,920
Food, textiles and footwear (8)	330	283	407	330	283	407
Fertilizers and agrochemicals (12, 15)	1,992	1,773	2,164	1,991	1,768	2,151
Resine, plastic and other chemicals (13, 14, 16)	1,665	1,242	1,123	1,722	1,231	1,122
Cemente and non-metalic mineral products (17, 18)	270	271	525	270	271	525
Steel and metal products (19)	697	905	890	697	905	890
Machines, equipments and vehicles (20, 22, 23, 24)	1,325	1,262	1,359	1,355	1,282	1,356
Other industries (9, 10, 21, 25, 27)	762	857	883	757	859	882
Construction (26)	185	242	396	185	242	396
Commerce (28)	217	258	406	217	258	406
Transport (29)	333	398	694	333	398	694
Services to companies (30)	410	417	682	410	417	682
Other services (31, 32, 33, 34)	410	484	819	377	451	785
Average salary	441	467	793	445	473	792

7 Identification and analysis of socio-economic indicators; illustrated by bioenergy systems in eight case study countries

JANSKE van EIJCK, ROCIO A. DIAZ-CHAVEZ, ALISON WRIGHT, JOUKE ROM COLTHOFF, PEDRO GERBER MACHADO, JORGE HILBERT, ABIGAIL FALLOT, DOMINIK RUTZ, RAINER JANSSEN, ARNALDO WALTER and ANDRÉ FAAIJ

Submitted[24]

Abstract

This chapter reports on the identification and analysis of a set of socio-economic indicators for bioenergy production based on five different types of feedstocks. Local impacts are often not discernible in data aggregated for the national level, especially where the sector is yet not fully developed. Furthermore, regional differences in socio-economic characteristics are significant, so that the impacts of bioenergy projects also differ substantially. Our analysis showed that it is essential to consider impacts at different scales, that is, the national, regional, and local levels. Background indicators (e.g. GDP in a region or unemployment rates), do not link directly to impacts of bioenergy, but can still provide useful information about the setting in which bioenergy projects are implemented. They can help identify potentially important issues (i.e., areas exhibiting risks of negative impacts or potential for positive impacts). Depending on the results of this check, more detailed indicators can be applied to give more precise insight into the nature and magnitude of potential local impacts. Furthermore, the study showed trade-offs between data accuracy and the practicability of data collection. This can vary per country and per feedstock. For new crops, the data is often not accurate and for low-income countries, such as Mozambique and Tanzania, the data is either not reliable or not available on a regional scale. More quantitative national, regional and local data is required to monitor impacts from biofuel production and conversion. Data collection could be facilitated by (inter)national bodies in collaboration with the private sector. Models that are used to quantify impacts on national and regional level for the long term, such as economic equilibrium-and input-output models, need to be further developed using more accurate, and less aggregated data. Lastly, environmental indicators, should also be taken into account, further research into interdependencies with socio-economic impacts is recommended.

[24] This chapter is based on research by the Global-Bio-Pact project, (supported by the European Commission) and is also partly funded by the Netherlands Enterprise Agency, RVO.nl.

7.1 Introduction

Worldwide production and trade in bioenergy has increased exponentially during the last few years, biodiesel production rose from less than 30PJ in 2000 to 572PJ in 2009 and ethanol production from 340PJ in 2000 to 1540PJ in 2009 (Lamers et al. 2011). However, a strong public debate on sustainability aspects for bioenergy emerged in the last years. This debate focused mainly on negative social and environmental impacts. As a consequence, several initiatives are set-up that are engaged in developing methodologies and tools to ensure sustainability of biofuels. One option to better ensure the sustainability of biofuels is the application of certification systems that use indicators which can be useful to share and compare information (Diaz-Chavez 2010). There is globally an increased focus on the development of sustainability certification schemes (van Dam et al. 2008b; van Dam et al. 2010b; Vissers et al. 2011). However, most of the existing sustainability certification schemes are not yet fully operational, although sustainable bioenergy production is required by e.g. EU biofuels directive (2009/28/EC 2009). Sustainability indicators may be used to measure the impact of the projects, and are at the same time a way to prioritise certain societal norms (Rametsteiner et al. 2011).

More than 100 indicators (social, economic and environmental) were already identified by Lewandowski and Faaij (2006), and around 67 sustainability certification initiatives relevant for bioenergy by Van Dam et al. (2010b). Vissers et al. (2011) furthermore compared 18 certification schemes that are suitable for biofuels for energy purposes. But there is a lack of unity and consensus among the different certification schemes (Vissers et al. 2011). There is a need to a further harmonization of the various certification schemes to come to a more uniform certification system (Janssen and Rutz 2011; van Dam and Junginger 2011). But also, criteria and indicators may sometimes be too general, vague and leave room for different interpretations (Lewandowski and Faaij 2006).

Furthermore, it appears that most of the sustainability certification schemes mainly considered environmental principles, even though there are serious concerns about socio-economic impacts of bioenergy production activities(van Dam et al. 2010b; German and Schoneveld 2012). Even within socio-economic indicators, more subjective well-being indicators are often not included (Rojas 2011). Recently, certification schemes have been developed that also include socio-economic aspects. Examples of sustainability certification systems that include socio-economic aspects are the, the *Principles and Criteria for Sustainable Biofuel*

Production, developed by the Roundtable of Sustainable Biofuels (RSB 2010), and the *NTA8080* (Netherlands Technical Agreement), developed by the Nederlands Normalisatie-institute (Dutch Normalization institute) (NEN 2011). There is also an international initiative that compiled *Sustainability Indicators for Bioenergy*, developed by the Global Bioenergy Partnership (GBEP 2011). But some of the indicators in these schemes and initiatives are not based on quantitative indicators, but on indicators that require compliance (e.g. is there a training programme [yes/no]) and most schemes are not yet fully operational or field-tested.

There is also a need to develop concrete and verified methodologies, to measure impacts of biofuel production under specific circumstances, such as for a specific region (Smeets et al. 2008). Examples of studies quantifying the impacts of bioenergy production are those by Arndt et al. (2009) and Herreras Martínez et al.(2013b), who respectively use a CGE model and an input/output analysis. However, these methods require a thorough understanding of modelling techniques and are time consuming, while there is a trade-off between the accuracy of sustainability indicators and the practicability (taking into account time and financial constraints). Furthermore, the applicability in developing countries, where (reliable) data is often lacking, and obtaining field data is tiresome due to cultural, infrastructural and other barriers, is different than in developed countries. While developing countries have a large potential for bioenergy feedstock supply (van der Hilst et al. 2011; Wicke et al. 2011; Batidzirai et al. 2012a), negative impacts could occur mainly in these countries, where existing laws are not sufficiently enforced or where the combination of formal and customary rights creates complex situations and loopholes in the system (German et al. 2011a).

The objectives of this chapter are: 1) to compile a broad inventory of potential socio-economic impacts and 2) to identify current options and indicators to measure those socio-economic impacts. Furthermore, 3) to apply these to case studies covering different countries and feedstocks, and 4) to select, apply and evaluate indicators. This will lead to 5) a set of indicators that can be used to assess socio-economic sustainability on different levels: national-, regional- and local level (company or project).

Section 7.2 shows the methodology that includes the impacts, indicators and methodologies, that are identified by current literature. In Section 7.2.2, the result section, the indicators that are applied to the case studies, are listed and evaluated. Section 7.4 covers the discussion while in Section 7.5 the conclusions and recommendations are presented. In Appendix A, additional information on the case study feedstocks and countries can be found, while in Appendix B, indicators values for the case studies are provided.

7.2 Methodology

First impacts and indicators, grouped by areas of concern, that are described in literature and that can be linked to bioenergy production are evaluated. From this overview , the most important areas of concern are selected and a variety of indicators are applied to eight case studies that vary greatly on a number of aspects (see section 7.3.1 for more details on the case studies). An indicator is a quantitative or qualitative variable that can be measured or described (Schut et al. 2014). By applying the indicators, i.e. obtaining the required data per case study, the practicability of the indicators is assessed; i.e. is it possible to measure the impact using that indicator with reasonable efforts (so taking time and resource constraints into account), but also whether the type of data that is required is available. Furthermore, the indicators are evaluated on their accuracy and usefulness. After this analysis, a comprehensive list is provided which includes indicators for which both practicability and usefulness were high. The values for the indicators that are applied to the case studies are provided in Appendix B.

Throughout this study a distinction is made between background indicators that measure the level of development of a region or country, unrelated to bioenergy projects, such as GDP and employment rates, and indicators that measure the specific impact of the bioenergy project or sector. To measure changes in impacts (performance), repeated measurements over time are required. This was not possible in this study therefore qualitative data and historical data is used as well. Compliance indicators are based on a yes/no basis and only indicate whether a certain requirement (such as e.g. do employees have access to medical health facilities) is fulfilled or not. For further details, see Diaz-Chavez(2010).Furthermore, impacts can be identified at different spatial levels; national, regional and local level.

7.2.1 Impacts and indicators identified by literature

Table 7-1 shows impacts that are mentioned in literature for different feedstock types. The list of impacts is created by analysing various literature sources (see table footnotes) on general impacts of bioenergy and specific impacts per feedstock of amongst others, the COMPETE[25] project (Janssen et al. 2009), (Kessler et al. 2007), (Smeets and Faaij 2010) and the RSB guidelines (RSB 2010). Furthermore specific literature has been used to establish impacts on gender related to biomass. Only main areas of concern are taken into account, while other areas of concern such as policy and governance aspects are described by e.g. (Diaz-Chavez 2010).

Table 7-1: List of most relevant socio-economic impacts for biofuels mentioned in literature, adapted from: (Van Dam et al. 2010a), (for sources see table footnote)

List of impacts mentioned in literature	Level of impact		
	National	Regional	Local
Economic aspects			
Poverty rate	•	•	
Contribution to economy			
• Direct effects	•	•	•
• Indirect and induced effects	•	•	•
(Improved) incomes and/or revenue (activities) in production areas		•	
(Improved) cash flow for consumption and savings		•	•
Equality in income and distribution (G)		•	•
Community infrastructure		•	
Employment generation/ social wellbeing / local prosperity			
Employment creation (improved employment rate) (G)	•	•	•
Employment structure (G)		•	•
Promote gender equality (G)		•	•
Impact on availability of traditional knowledge (G)		•	•
Increased needs for basic infrastructure and services		•	
Access to education		•	
Existence of social conflicts		•	
Impact on graves or other cultural heritage sites		•	•
Disruption of structure of settlements		•	•
Increased crime		•	•
Competition with traditional uses		•	•
Disruption of social networks and relationships		•	•
Access and availability of energy resources		•	•
Working conditions and rights			
Freedom of association and collective bargaining			•
No forced labour			•
No child labour			•
No discrimination (including equal payment in work) (G)			•
Wages			•
For temporal, seasonal workers			
For fixed jobs			
Adequate standard of living (e.g. food, shelter and health services)			•
Safe and healthy working conditions (G)			•
Reasonable limitation of working hours			•
Social security for (migrant) workers			•

[25] Bioenergy Competence Platform for Africa (COMPETE), www.compete-bioafrica.net

(Vocational) training possibilities			•
Protection against unemployment			•
Health and safety impacts			
Health impacts - general [(G)]			•
Access to sufficient potable water			•
Increased risk of HIV/Aids or other diseases			•
Availability of health and education services		•	
Access to health and education services		•	
Food security [(G)]			
Impact on food availability in producing region		•	
Food access		•	•
Food distribution		•	•
Impacts on food and feed prices	•	•	
Ability to maintain household food production			•
Ability to purchase food			•
Land tenure and rights			
Respect land rights and avoid displacement [(G)]		•	•
Land right conflicts		•	•
Land competition: impact on land prices	•	•	
Tenure security / insecurity		•	•
Loss of land rights and entitlements		•	•
Compensation of land		•	•
Less access to land (reduced availability)		•	
Loss of land and natural resources	•	•	
Loss of crops and cleared arable land	•	•	
Loss of natural resources and grazing land	•	•	
Participatory aspects (gender)			
Women’s participation in planning			•
Skills transfer		•	•

Sources: (Susila W.R. 2004; Dutch Soy Coalition 2006; Van Berkum et al. 2006; Balsadi O.V. 2007; Kessler et al. 2007; Steward 2007; Aidenvironment 2008; Barber et al. 2008; BNDES and CGEE 2008a; Goldemberg et al. 2008; OECD/IEA 2008; ProForest Ltd. 2008; Rossi and Lambrou 2008; Rulli 2008; Crowe et al. 2009; Janssen et al. 2009; Oeko-Institut and UNEP 2009; RSB 2009a; Rutz D. and Janssen R. 2009; Tomei and Upham 2009; van Dam et al. 2009b; Vanwey L. 2009; Wicke et al. 2009; Brittaine and Lutaladio 2010; Eisentraut A. 2010; Rist L. et al. 2010; Smeets and Faaij 2010; Janssen and Rutz 2011; Rutz et al. 2011; Herreras Martínez et al. 2013b; Van Eijck et al. 2013).

The impacts of bioenergy projects take place on different levels (national, regional, local), affect different stakeholders (employees, employers, households etc.), apply to different parts of the value chain: production, (sometimes pre-processing) conversion, and consumption, and link to different phases of project implementation (at start-up, at implementation itself, after the project etc.).

7.2.2 Indicators identified by literature

Sustainability indicators can be useful in showing the interconnections between changes in the economy, the environment and society. Their primary function lies in simplification: indicators are a compromise between scientific accuracy and the demand for concise information (Diaz-Chavez 2003). There has been a great deal of work on indicators; they apply to different actors, on different parts of the value chain and at different periods in time. Indicators and principles that are already available in literature (mainly GBEP and RSB) are provided in Table 7-2 below; this list is not exhaustive but captures the most relevant indicators.

Table 7-2: Socio-economic areas of concern, criteria and indicators based on (GBEP 2011), (RSB 2010) and (Van Eijck et al. 2012) and (Van Eijck et al. 2013)

Area of concern	Criteria	Indicator
Economic feasibility	-Bioenergy production activities shall be financially viable	• NPV [€ or USD] • IRR [%] • PBP [years] • Production costs [€ or USD/ton SVO] • Profitability [€ or USD/year] • Competitiveness biofuel compared with alternatives such as fossil diesel [$/l]
Employment, Rural and social development, energy access	-The socio-economic position of local stakeholders shall be improved through the impact of biofuel operations	• Job creation in the bioenergy sector or company [nr] • Ratio skilled/unskilled jobs [%] • Ratio permanent/temporary jobs [%] • Net Job creation per hectare [jobs/hectare] • Gross value added • Productivity • Comparison wages in the biofuel company to comparable sector/national average [USD/month] • Change in income • Change in share of people below the poverty line [%] • Change in GDP [USD/year] • Purchasing power [USD/year] • Life expectancy [years] • Literacy rate [%] • GINI-index [-] • Regional unemployment rate compared to national average [%] • Contribution to education, health care and infrastructure investments • Share of total regional investments by biofuel project [%] • Bioenergy used to expand access to modern energy services

		• Energy diversity
Labour and working conditions	-Bioenergy production activities shall not violate labour rights -Bioenergy production activities shall ensure decent work and the well-being of workers -No forced labour or child labour shall occur on bioenergy production activities -Workers shall have the right to organize, collectively bargain and the right to associate -Workers shall not be discriminated in any way, including gender	• Relevant (inter-)national regulations obeyed [yes/no] • Amount of forced labour [positive/negative] • Amount of child labour [positive/negative] • Rate of discrimination [positive/negative] • Formation of unions [positive/negative] • Number of work related accidents and health issues [positive/negative] • Safety gear provided [yes/no] • Secondary benefits provided [-] • Working hours [maximum working hours and overtime payment schedule] • Training and/or education provided to employees yes/no]
Health and safety impacts		• Change in mortality and burden of disease attributable to indoor smoke • Incidence of occupational injury, illness and fatalities
Food security	-The bioenergy production shall not threaten food security -The bioenergy production shall ensure the human right to food access	• Availability of main staple crops [tonnes/year] • Change in yields of main staple crops [tonnes/hectare] • Land converted from food crops for bioenergy feedstock production [hectares] • Change in prices of the 5 main staple crops (food basket)[€/tonnes] • Price and supply of a national food basket • Change in share of expenditures households spent on food [%] • Competition for labour [yes/no] • Change of perception by people affected by bioenergy production regarding food security [positive/negative] • Change in undernourishment [%]
Land rights	-Biofuel production activities shall respect land rights and land use	• Land acquisition process [positive/negative]

	rights. -Existing land rights will be assessed, documented and established. This holds both for formal and informal land rights. The allocation of land for biofuel production will only be established when these rights are determined. -Acquisition or voluntary resettlement of land for biofuel production will always be compensated	• Amount of land under new ownership [ha] • Land compensation [positive/negative] • Change in access to land [positive/negative] • Share of land acquisitions that have complied with formal or socially accepted procedure regarding absolute numbers and area [%]
Gender		• Change in unpaid time spent by woman and children in collecting biomass

Different types of indicators exists: performance indicators (against a preselected set by e.g. regulations or certification schemes), impact indicators (measuring impact over time), composite indicators or index (where several indicators are aggregated). Furthermore, indicators can be applied at different points in time, for example: ex-ante, at the implementation phase (early or after several years) or monitoring impacts to follow up after projects have been implemented or ended, lastly, also projections for the future could be covered through modeling. Indicators may change according to the objective of their application as well as the final use they will have e.g. monitoring, assessment, or others (Diaz-Chavez 2014).

An important aspect of the evaluation of the indicators is the assessment of the practicability and accuracy. Practicability means the availability of data and the effort that is required to collect and process the data (in terms of time). A higher accuracy means a higher degree of closeness of the collected data to the impact that the indicator aims to measure, the reliability and consistency of the collected data and whether the indicator is easy to comprehend. This is evaluated per area of concern in the result section.

7.2.3 Case study selection and data collection

In order to generate data on the ground, eight in-depth case studies were investigated on socio-economic impacts. The impacts are assessed on different levels, including the national, regional, and local (company or project level). The case studies at the national level were selected in order to balance the geographical distribution (Africa, Latin America, Asia, Europe, North America), feedstock sources, annual as well as perennial and mechanised and manually cultivated, (soy, palm oil, jatropha, sugarcane, lignocellulosic feedstock), and products (Straight Vegetable Oil (SVO), biodiesel, ethanol, bio-products). Canada is not a developing country but was included because there were no 2nd generation biofuel projects in the other countries. Furthermore, the level of development and size of the countries is very different, although the term developing is broadly used in the literature.

See Figure 7-1 and Table 7-3 for an overview of the selected case studies.

Figure 7-1: Geographical view of selected case study countries

In this study, the regional level is defined as a homogenous region in climate, soil, and socio-economic parameters. The size of the region depends on the country and can be a province or district. The local area refers to the area where the biomass feedstock (including by-products) is produced and/or converted into the final or intermediate product, see Table 7-3.

The data collection has mainly been performed by local country partners[26]and own fieldwork during 2010-2012 by interviews, observations, sometimes surveys and by reviewing (company) literature and statistical data. Several field visits have taken place and additional (national) literature and international databases such as FAOSTAT, were used to verify and update data. On a local level, specific projects were visited and companies cooperated in providing data, these are listed in the footnotes in the table below.

Table 7-3: Case studies included in this study, based on the Global Bio Pact project and Jatropha data collection project

Feedstock type	Biofuel or product	Case study country	Sector description	Region	Project/village/company
Soy	biodiesel	Argentina (ARG)	Well established	Buenos Aires, Santa Fe, Santiago del Estero	Plant X in Roldán and AG Bioenergy plant in Frias[a]
Palm oil	biodiesel	Indonesia (IDN)	Palm oil well established, biodiesel slightly less	North Sumatra	Aek Raso Plantation and Mill, Desa Asam Jawa and Harapan Makmur[b]
Jatropha	SVO And	Mali (MLI)	In development	Koulikouro	Mali Biocarburant SA, Garalo Bagani Yeelen (+6 projects)[c]
	biodiesel	Tanzania (TZA)	In development	Kisarawe Arusha	Leguruki Village[d]
		Mozam-bique (MOZ)	In development	Various	Various, 6 projects[e]
Sugarcane	Bio-ethanol	Brazil (BRA)	Sugarcane well established, ethanol slightly less	Northeast Brazil	São Fransisco Mill (São Paulo) and Pindorama Mill (Alagoas)[f]
		Costa Rica (CRI)	Sugarcane well established, ethanol less	-	CATSA in Guanacaste[g]
Lignocellu losic biomass 2nd generatio n	Ethanol (from woody biomass)	Canada (CAN)	Forestry well established ethanol not	British Columbia	Lignol, location Tembec (Kootenay area)[h]

[a]: The data is collected by interviews and visits at two companies; one is plant X in Roldán in the province of Santa Fe which is a biodiesel production plant (no feedstock production). The company exports 75% of its production and receives nearly 900 tons of soybean oil per day, producing 724 ton soy biodiesel per day or 250,000 tons per year. The second company, AG Bioenergy Viluco plant, is located in the southwest of the province of Santiago del Estero and is an integrated company producing feedstock and biodiesel. The location of the company does not belong to the core soy area but is within the boundaries of the agricultural frontier expansion. The company started in 1973 as a construction company and in 1995 the company went into agricultural and livestock production. The industrial complex AG Energy Plant is located in Frias, Santiago del Estero, and has 4 process plants and one

[26]In Costa Rica data is collected by CATSA, in Brazil by Unicamp/CTBE, in Argentina by INTA, in Indonesia by Greenlight biofuels, in Mali by the Mali Folkecenter, in Tanzania partly by TaTEDO, and in Mozambique partly by IIAM.

movement plant. They receive soybean grains, pre-clean and stock them and then transported to the process plant. The oil is extracted by chemical extraction and soy meal is the by-product. Additional data was collected in 2012 and is described in (Vuohelainen and Diaz-Chavez 2012) and (Diaz-Chavez and Vuohelainen 2014).

[b]:The data is collected at 4 sites; (1) Aek Raso Plantation in Labuhan Batu District of North Sumatra. This is a state-owned plantation (3,800ha) established in 1983 with an associated plasma smallholder (outgrowers) scheme (7,200 ha). (2) Independent smallholders in Desa Asam Jawa (1,220 ha, average plot size of the sample studied is 1.5-4ha), also in Labuhan Batu District, a reasonably well situated location. (3) Independent smallholders in Harapan Makmur, Tanjung Jabung Timor District of Jambi province. Here they only started cultivation in 2005 on 1,500 ha of on average 2ha plots. (4) Aek Raso mill, located on Aek Raso Plantation. This mill processes FFBs from its own plantation (55%), from outgrowers (29%) and from small private plantations and independent smallholders (16%). They annually purchase 122,000 t FFBs (or daily 463 t FFBs) and the capacity is 30 Mt FFB/hour, with a 24 h/day production during peak production season producing daily 106.5 t CPO. Data was obtained by interviews (individually and group interviews), except for the mill, for each location at least 5 smallholders were interviewed.

[c]: Data is collected at two projects, Mali Biocarburant and Garalo Bagani Yeelen. In the private jatropha sector, the leading company is Mali Biocarburant SA which has been supporting around 3,000 farmers since 2007, and processes Jatropha SVO and biodiesel in their processing unit in Koulikouro which is the only processing unit in operation in the country and produces max. 2000 liter/day. The jatropha is sourced from outgrowers and independent smallholders. The leading NGO is Mali-Folkecenter Nyetta, who implemented the Garalo Bagani Yeelen project which started in 2006 and provides electricity from jatropha oil (but currently fossil diesel) in a hybrid power station to around 400 households. In 2008 an area of 440 ha was planted (of which 80 ha was unsuccessful) by individual farmers (95%) and collective farmer fields (5%).

[d]: The data is collected in the village Leguruki in Arusha region. Jatropha smallholders cultivate jatropha (often as hedge) and there is an Energy Services Platform installed, that produces electricity and is connected to around 25 households and 17 small shops or restaurants. The total village area is 2,185 ha and the population is 4,000. Around 99-100% of the population own land without official title.

[e]: Data is collected at 6 (large scale) plantation companies; AVIAM, ADPP, Niquel, Sun Biofuels, Moçamgalp and SAB. Data is collected on management and employee-level and at communities in the direct vicinity of the Jatropha projects as well as at local authorities that are directly involved with the projects; the data is collected from March-May 2012 and in June 2012. The main regions that are studied are Nampula and Gaza-Inhambane.

[f]: The data is collected at two sugar mills, one in the NE; Pindorama, and one in the CS; São Francisco Mill. The São Fransisco Mill is located north of São Paulo state and is the largest organic (no chemical fertilisers or pesticides) sugarcane producer in the world. The production in 2009 was 1.3 million tonnes of sugarcane (company data) and 65,000 l ethanol, on in total 13,500 ha. The Pindorama mill is located in the state of Alagoas and is a cooperative which was created in 1956. The cooperative consist nowadays of 1160 small producers who own the mill and supply the sugarcane on a total of 32,000 ha (incl. areas for fruits) on plots that range from 9 to 25 ha. They produce ethanol since 1982; in 2009/2010 ethanol production was around 35.6 million liters (50% sugar and 50% ethanol). Additional data collection took place at J. Pilon, see (Vuohelainen and Diaz-Chavez 2012) and (Diaz-Chavez and Vuohelainen 2014).

[g]: Central Azucarera Tempisque Sociedad Anónima (CATSA). This company was founded in 1975, is ISO 9001 certified since 2001 and ISC certified since December 2010. The capacity is 25 Ml of ethanol and they are currently producing 13 Ml. The sugarcane is sourced from their own land and additionally from 1049 independent producers representing 27% of the sugarcane processed in the factory. The company

only produces electricity for its own use during the 4 months of harvest, there is no additional heat and power production due to unfavourable electricity tariffs. Data is collected by interviews with various stakeholders.

[h]: The local case study is with data from Lignol, location Tembec, which is one of the largest forest product companies in Canada and has one of the largest estates of certified forestry operations. Tembec Industries Inc. started in 1999 in British Columbia, has sales of approximately 4 billion $ and 11,000 employees, operating 50 market pulp, paper and wood-product manufacturing units that produce chemicals from by-products of its pulping process. In 2007 most of the forest management tenures in Kootenay were certified, in this case study only the certified units are focussed on. Lignol wants to develop a pilot plant where the technique is tested and further developed, with a capacity of 200-300 tonnes dry biomass/day.

The production system and key characteristics per feedstock are described in Appendix A. Furthermore, specific country aspects including data on the current size of the sector, the policy environment and key socio economic characteristics are also provided.

Two definitions are used in this chapter; 'smallholders;' are independent producers that are free to sell to any buyer. And 'outgrowers;' are farmers that produce feedstock under contractual arrangements for a processor or plantation company (in Indonesia also referred to as 'plasma smallholders'(Obidzinski et al. 2012)).

7.3 Results

7.3.1 Economic indicators

In Figure 7-2 the indicator GDP per capita is shown. This gives a classification of the relative level of development of countries on a global level; high (Canada), middle (Brazil, Argentina, Costa Rica) or low income countries (Mali, Tanzania, Mozambique).

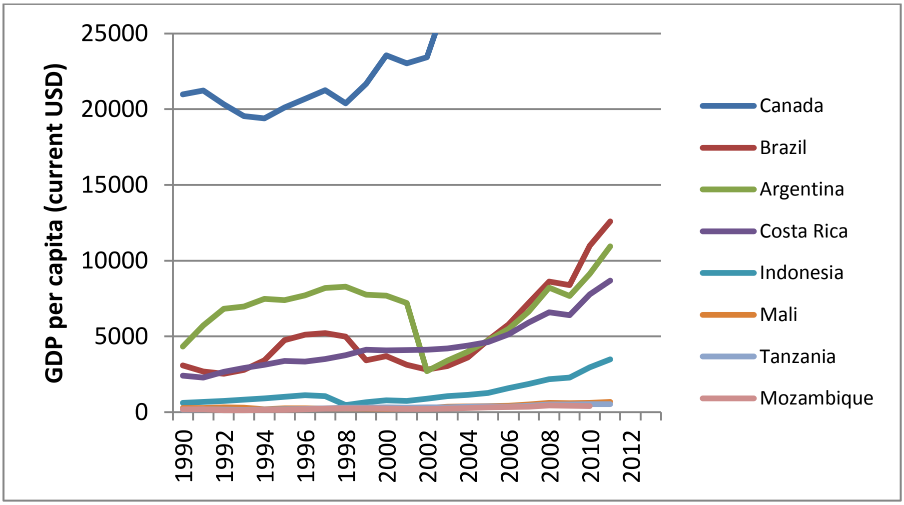


Figure 7-2: GDP per capita development from 1990-2011 in the case study countries, the value for Canada in 2011 is >50,000, source (World Bank 2011)

In Table B12, Table B13, and Table B14 in Appendix B, the indicators are listed with values of the case studies for which data was available. Due to the length of the tables, the indicators for national-, regional- and local issues are separated. In Table 7-4 below, the economic indicators are listed.

Table 7-4: Summary of available indicators for economic analyses by the case studies

No.	Economic indicators	Qn Ql[a]	Measurement method	National	Regional	Local
	Background indicators					
-	GDP or GRDP [€ or $]	Qn	Statistical data	•	•	
-	GDP per capita [€ or $] (or regional per capita income compared to national)	Qn	Statistical data	•	•	
-	GINI coefficient (or regional GINI compared to national) [nr] or [%]	Qn	Statistical data	•	•	
-	People below poverty line of 2 $/day [%]	Qn	Statistical data	•	•	
-	Human Development Index (HDI)	Qn	Statistical data	•		
	Impact/ specific indicators					
1.1	Sector contribution to GDP or GRDP [%]	Qn	Statistical data or input/output analysis	•	•	
1.2	Sector contribution to agricultural GDP	Qn	Statistical data	•	•	
1.3	Value of the sector (by revenue or turnover generated by the sector [€ or $] (in combination with 1.1)	Qn	Statistical data	•	•	

1.4	Investments in the sector [€ or $], or as percentage of total investments [%]	Qn	Statistical data	•	•	
1.5	Amount of revenue (taxes, royalties) collected from the bioenergy sector [€ or $]	Qn	Statistical analysis	•	•	
1.6	Bio products exported [tonnes or litres] as percentage of total worldwide production of the same bioenergy feedstock or product [%] or of total exports [%]	Qn	Statistical data and analysis	•	•	
1.7	Total investment in bioenergy infrastructure over the past decade [€ or $]	Qn	Statistical data	•	•	
1.8	Value of industrial inputs in the bioenergy sector [€ or $]	Qn	Statistical data	•	•	
1.9	Volume of bioenergy production by business model (eg large plantations and smallholders)	Qn	Statistical data and analysis	•	•	
1.10	Share of income for large companies and smallholders	Qn	Statistical analysis			
1.11	Contribution of feedstock sales to household income (% or absolute value)	Qn	Smallholder records and interviews			•
1.12	Cost of feedstock production [$/GJ] compared to other alternatives	Qn	Company records and interviews			•
1.13	Cost of feedstock conversion [$/GJ] compared to other alternatives	Qn	Company records and interviews			•
1.14	Total project investments [€ or $]	Qn	Interviews			•
1.15	Labour costs [$/tonne or litre]	Qn	Literature / interviews			•
1.16	Feedstock price [€ or $]	Qn	Literature / interviews			•
1.17	Product selling prices [€ or $]	Qn	Literature / interviews			•
1.18	Net Present Value (NPV) [€ or $]	Qn	Cost Benefit Analysis (CBA)			•
1.19	Internal Rate of Return (IRR) [%]	Qn	Interviews, CBA			•
1.20	Pay Back Period (PBP) [yr]	Qn	Interviews, company docs			•
1.21	Turnover of the company (revenue generated) [€ or $]	Qn	Interviews			•
1.22	Revenue per ha from bioenergy crop compared to revenues of other crops [$/ha]	Qn	literature and/or interviews			•
1.23	Competitiveness of the biofuel compared to the fossil alternative	Qn	Literature, observation			•

All indicators link to both production and conversion in the value chain. All indicators can be assessed on an ex-ante basis using estimates, but values should be updated during implementation because the estimates can differ significantly from actual values (demonstrated by jatropha projects in Mozambique). Economic profitability of the projects is important on a local scale, because only if the projects are financially feasible, economic sustainability is achieved on a long term and (positive) impacts may then reflect on a regional and national scale.

Evaluation of indicators

The majority of the national economic indicators are used and collected by global organizations such as FAO, UNDP, the World Bank and so on. Statistical data is collected by e.g. national governments on GINI index, sectoral GDP contribution, number of jobs per sector etc., but since the bioenergy sector is relatively new, this sector is often not disaggregated. Values for a disaggregated bioenergy sector are only available in countries where this sector is active since a relatively long period of time, e.g. in Brazil since 1970, and in Argentina and Indonesia that have well established soy and palm sectors. When this value is not available in statistics, an input-output analysis can be applied, which can model the impact of the sector on GDP, imports and employment (Wicke et al. 2009). An input-output model can be applied to a nation, or to smaller areas such as regions (see below). However, input-output tables are needed per country to be able to make such an analysis as well as capabilities to perform the analyses. A General Equilibrium Model (CGE) can provide even more detailed information, but this requires more technological capabilities at the organisations that perform the analyses.

To be able to obtain insight in the relative size of the bioenergy sector, several indicators were used but they were often only available in one country alone. ‘Contribution of the bioenergy sector to agricultural GDP’ for example was only available for Costa Rica. And ‘estimated value of the sector’ only for the forestry sector in Canada and the sugarcane sector in Brazil. Indonesia and Argentina were able to provide information in absolute terms on exported biofuels, but the amount of liters or tonnes alone does not provide a measurement of the relative size of the sector in global perspective. Additional information is therefore required on the share the export has in global biofuel production/export.

Only Canada was able to provide information on the total value of investments in the bioenergy sector, in the other countries this type of information is not recorded. Another indicator is required to establish the relative size of the sector. Also for investments in bioenergy infrastructure, no data was obtained, while for ‘value of industrial inputs’ only Brazil was able to provide data.

Providing quantities of production by business model (e.g. large plantations vs smallholders), gives insight in the structure of the sector. If policy makers want to include smallholders this type of information is essential.

Regional indicators

Socio-economic differences between regions (provinces or agro-ecological zones) in developing countries can be large. Urban areas for example, have much higher GDPs per capita but often also lower fossil fuel prices than rural areas. Even between two rural areas differences in e.g. wage rate, unemployment ratio etc. can be large (see two regions in Mozambique, Gaza and Nampula in (Van der Hilst et al. 2013). Therefore, bioenergy projects may have a much larger positive effect on the regional economy than if their effect would be compared to national averages. However, regional general data e.g. on GDP or GINI index is hardly monitored in developing countries which makes it difficult to calculate regional impacts of bioenergy projects. It is also possible to model these impacts, e.g. by using a regional input-output model (Herreras Martínez et al. 2013b). This model generates data on the impact of a bioenergy sector in a region on GDP, imports and employment and shows interlinkages between regions by comparing (potential) regional employment figures to regional unemployment rates, possible migration of labourers can be calculated.

Local level (micro)

Because the impacts on a local scale are project specific, the indicators have to be assessed for each project. If a business plan is publically made available, acquiring the IRR or NPV of a project is relatively easy (see case study Mozambique). However, in reality the exact cost figures are likely to be different than the estimated ones and sometimes they can be based on false assumptions. This is especially the case for crops for which little commercial experience exists, such as Jatropha. If these figures are not available, an extensive financial analysis has to be conducted which is very time-consuming (Van Eijck et al. 2013). Accuracy improves if the values are accompanied by the assumptions they are based on (e.g. expected yield). The various units that are used in these calculations makes comparison complex, using uniform data formats would improve this.

Although the generation of value added by the bioenergy sector is a positive effect, the distribution of profits is an important theme. Wage levels, minimum wages, possibly gender disaggregated wage data but also the ratio of profits that stay in a country or goes abroad, can assist in assessing distribution. Indicators on employment generation and wages are included in the next area of concern: employment - local prosperity, which is why the two areas of concern should be analysed in conjunction.

The contribution of a bioenergy project to household income is an important positive effect, but it does not give information about other (potentially more profitable) opportunities (or the lack thereof). Opportunity costs can be calculated by assessing the revenue per ha for a certain bioenergy crop and compare this to other crops, see e.g. Van Eijck et al. (2012), for a comparison between jatropha, cassava and eucalyptus for smallholder farmers. It is also possible to compare the indicators that link to a local level (production costs, NPV etc.) to other companies in the same sector or same-size companies in other sectors.

7.3.2 Employment generation / local prosperity / social well-being

In Table B15 in Appendix B, the indicators are listed with values of the case studies for which data was available. In Table 7-5 below, the indicators for employment generation, energy access and educationare listed. This area of concern is closely linked to the economic feasibility of a production system. The indicators listed below can be used throughout the whole value chain.

Table 7-5: Summary of available employment, local prosperity, social well-being indicators by the case studies

2	Employment indicators	Qn/Ql	Measurement method	National	Regional	Local
	Background indicators					
-	Total labour force [nr]	Qn	Statistical data	•	•	
-	Unemployment ratio [%]	Qn	Statistical data	•	•	
-	Average minimum wage [$/day or month]	Qn	Statistical data	•		
-	Total electricity generated	Qn	Statistical data	•	•	•
-	Total energy consumption	Qn	Statistical data	•		
-	% of biomass in energy mix	Qn	Statistical data	•		
-	% of population lacking electricity access by grid	Qn	Statistical data	•	•	
-	% or value of petroleum products imported	Qn	Statistical data	•		
-	Firewood and charcoal demand	Qn	Statistical data	•	•	
-	General education level	Qn	Statistical data	•	•	
2.1	Employment generation [no of jobs]or [jobs/ ton biofuel]	Qn	Statistical data or input/output analysis, Company records and interviews	•	•	•
2.2	Employment generation per ha or	Qn	Company records and			•

	tonne biofuel [jobs/ha or jobs/t]		interviews			
2.3	Percentage of informal jobs	Qn	Interviews and statistics	•	•	
2.4	Ratio of permanent contract versus temporary or casual/daily workers	Qn	Company records and interviews			•
2.5	Ratio skilled versus unskilled jobs	Qn	Company records and interviews			•
2.6	Ratio between local and migrant workers	Qn	Company records, interviews			•
2.7	Wage levels at the bioenergy company (including casual workers) compared to minimum wages	Qn	Company records and interviews			•
2.8	Average wage in the company	Qn Ql	Company records and interviews			•
2.9	Salary variation compared to crop price development	Qn		•		
2.10	Total wages and salaries in the sector	Qn	Sector level labour statistics	•		
2.11	Income earned by smallholders [$/ha or tonne]	Qn	Interviews, literature			•
2.12	Share of income for large companies and smallholders	Qn	Sector level labour statistics (if available) or company records	•		
2.13	Job growth rate	Qn	Sector level labour statistics	•	•	•
2.14	Average age of employees	Qn	Sector level labour statistics	•		•
2.15	Participation of different races	Qn	Sector level labour statistics, company records and interviews			•
2.16	Wages at farm/company compared to wages in traditional activities (like charcoal making, food production)	Qn	Interviews and statistics			•
2.17	Wage levels sufficient to buy food and other household needs?	Ql	Interviews and statistics			•
2.18	Person-days used on biofuel activities by family labour (Threshold: Sufficient time left to grow own food (in case wages too low to buy all food)	Qn	Interviews and statistics			•
2.19	Employment in the bioenergy sector as % of unemployment	Qn	Sector level labour statistics	•	•	
2.20	Population that has increased energy access through bioenergy	Qn	Statistical data	•	•	•
2.21	Education level of the employees	Ql	Interviews, company documents			•
2.22	Education and training provided by company	Ql	Interviews, company documents			•
2.23	Community investment	Qn	Interviews, company documents		•	•

Quantitative (Qn) or Qualitative (Ql)

Results vary widely for number of jobs per hectare in the cultivation phase, ranging e.g. from 0.03 up to 1.03 jobs per hectare in Mozambique. At the 6 jatropha projects included in our analysis in total of about 800 jobs were created. The skilled versus unskilled jobs ratio provides more details on the structure of the labour force ; in Mozambique for example, the majority of the jobs at Jatropha projects are unskilled, about one seventh was skilled (see Appendix B). Permanent jobs are preferred over temporary jobs, because it ensures more security for the workers. However, most crops can only be harvested seasonally. In Mozambique at the 6 jatropha projects in total about 500 permanent jobs were created in the cultivation phase and 300 temporary ones (see Appendix B). Even though this is only a fraction of the total labour force of 11 million, because the unemployment rates of the regions in which the bioenergy companies operate are high (e.g., > 100,000 people in Nampula region (Van der Hilst et al. 2013)), and opportunities limited, job creation has a positive impact on the local economy. Job creation at the industrial level is also important, results were easily obtained from Brazil and Argentina, but in Mozambique, Tanzania and Mali there is hardly an industrial biofuel sector.

This is also the case in the Argentinean soy sector as employees in this sector do not work for a full year, and conversion plants close for a few months per year. To understand the evolution of the salaries in the Argentinean soy sector, the evolution of the non-registered salaries published by INDEC are analysed, see Figure 7B-4 in Appendix B. The trend of increased soy prices is followed by the salaries of the non-registered sector which also increase, therefore this is a good proxy of the salaries of the agricultural sector and more precisely the soybean sector(Sbarra and Hilbert 2011). However, this type of data is not available for the other case study countries.

Minimum wages are in all case study countries legally required. In the analysed biofuel projects all wages were above minimum wage, although it is necessary to check this at different levels (management as well as employees). Data about job creation at individual projects was available from interviews with project management and local communities.

Only Brazil was able to provide some details on the education level in the region and of employees in the sector (e.g. 60% of the population in the North East (NE) have studies less than 9 years, sugarcane sector employees have on average 5.7 years of education, in the NE 3.7 yrs) and in the case study companies (see Appendix B). In Indonesia and Mozambique only very general observations could be provided such as a lack of knowledge on planting materials at the case study company in Indonesia (see Appendix B). Especially small scale projects, such as some jatropha projects in Tanzania have information available on increased energy access due to bioenergy projects (Sawe et al. 2011). For larger sectors such as soy in Argentina this is not a point of concern (Sbarra and Hilbert 2011).

Evaluation of indicators

In ex ante impact assessments employment generation is often an important parameter; while in certification systems there is usually no criterion for the number of jobs to be created as they are in general compliance indicators. Some indicators can be more challenging to measure such as minimum wage e.g. for contract workers that are paid by unit. Nevertheless, other Important questions are: Can they live from their wage? Do they have the possibility to bargain? Do they get a contract? Working conditions are analysed in the next section.

Indicators need to be specified well: there could be a difference between the number of workers and the number of jobs (in fulltime-equivalent (fte)). Also the categories of educational levels vary between the case studies (unskilled, semi-skilled, skilled labour versus more detailed educational level indications).

Disaggregated unemployment figures per region were hard to obtain, while differences between regions can be large. The location of e.g. a conversion plant could have a more positive impact in a region with very high unemployment figures, e.g. the difference between Nampula and Gaza-Inhambane in Mozambique (Van der Hilst et al. 2013).

During harvest time, the case study company in Costa Rica brings 300 workers from Nicaragua for a lower wage than local employees, illustrating that the moment data are obtained is also important in analysing and understanding results obtained.

To obtain an overview of the total employment effects, i.e. job generation due to bioenergy production, but also effects and job shift in other sectors such as producing sectors, including indirect effects, an input-output model or CGE-model has to be applied. This is for example done by Wicke et al. (2009) for Argentina, by Arndt et al. (2009) for Mozambique and by Herreras Martínez et al. (2013b) for NE Brazil.

A number of bioenergy projects contribute to increased energy access, for example by generating electricity. The indicator ‘increased energy access’, can be measured in absolute terms (no. of households with increased access) or in relative terms (% of the population with increased access). If local bioenergy projects replace other forms of energy provision (e.g. jatropha fuel instead of diesel in a generator), only the net effect should be calculated.

7.3.3 Working conditions and rights

Table 7-6 below shows an overview of the indicators, while Table B16 in Appendix B shows the values for the working conditions related indicators of the case studies. They all relate to local scale impacts.

Table 7-6: Summary/Overview of available working conditions related indicators by the case studies (including 6 indicators from previous area of concern)

3	Working condition and rightsindicators		Measurement method
2.6	Wage levels at the bioenergy company (including casual workers) compared to minimum wages	Qn	Company records and interviews
2.7	Average wage in the company	Qn Ql	Company records and interviews
2.13	Average age of employees	Qn	Sector level labour statistics
2.14	Participation of different races	Qn	Sector level labour statistics, company records and interviews
2.15	Wages at farm/company compared to wages in traditional activities (like charcoal making, food production)	Qn	Interviews and analysis
2.16	Wage levels sufficient to buy food and other household needs?	Ql	Interviews and analysis
3.1	Income spent on basic needs	Qn	Interview, company records
3.2	Occurrence of forced labour	Ql	Interviews with management and workers
3.3	Maximal and average number of hours of work per day	Qn	Workers' contracts, company records and interviews
3.4	Right to collective bargaining / respecting trade unions (freedom of associations)	Ql	Company records and interviews NGO monitoring records
3.5	Extent to which child labour laws / minimum age are complied with.	Qn	Company records and interviews NGO monitoring records
3.6	Number of work related accidents	Qn	Company records and interviews
3.7	Level of provision of Operational Safety and Health systems, training and protective equipment	Ql	Company records and interviews
3.8	Extent to which legal requirements for social security and accident insurance are complied with	Ql	Company records and interviews
3.9	Number of unjustified dismissals / end of contracts / resignations	Qn	Sector level labour statistics
3.10	Duration of breaks	Qn	Workers's contracts, company records and interviews
3.11	Mode of transport to the fields	Ql	Company records and interviews
3.12	Right of training/education	Ql	Company records and interviews
3.13	Possibilities of retirement pension		Company records and interviews
3.14	Change in access to health insurance	Ql	Company records and interviews

3.15	Rights of casual workers (social security, medical assistance) compared to fully employed workers	Ql	Interviews
3.16	Right to understand the employment contract	Ql	Interviews, language employment contract versus language employee
3.17	Other benefits provided	Ql	Company records and interviews

Quantitative (Qn) or Qualitative (Ql)

The data for all indicators in this area of concern have to be obtained by interviews (both management and employees) and can be verified with company data and reviewing contracts. Data on the international and national child labour standards can be acquired from the International Labour Organisation (ILO 2010).

Some indicators are relevant for one country but less relevant for another country. For example, although the right to collective bargaining and to be a member of a trade union is widely accepted as an important indicator but varies considerably according to the national Laws of different countries. , the indicator regarding compliance with child labour laws was not used by all case study countries since it is not a significant issue in some of these countries. Possibilities for retirement pension are only relevant in countries that have a pension system, while in countries without such systems, retirement itself can be an issue. Some indicators are difficult to measure; for instance the number of work related accidents is not always recorded, and the interviewed company owner might have its reservations towards answering this question. Regarding collective bargaining, it can be useful to distinguish between the firm’s own employee association and third party trade unions.

Evaluation of indicators

Working conditions are an important issue in many existing certification systems and companies should comply with national regulations. Bargaining, free access to trade unions and occupational safety and health (OSH) are relevant. It is observed that the way data is collected is a critical issue; interviews with company owners can be easily result in biased outcomes, stressing the importance of professional third party auditing including interviews with workers.

Sometimes ‘other benefits’ that are provided to communities or employees, are verbal agreements rather than a quantifiable (financial) amounts (eg. building a medical center or educating teachers). The indicators should leave room for adding these additional benefits. In some cases, these verbal agreements are not executed, therefore actually implemented benefits should be focussed on.

Workers can elaborate on the project management's policy by explaining why they started working for the project, their age, salary, working hours and breaks and how operations are executed. However, the results of the data collection, in Mozambique, show some variations due to misinterpretation of the question by the workers; the workers for example indicate the age of the youngest person working at the project instead of the minimum age to be allowed to work at the project. So definitions and concepts used for qualitative data collection in surveys and interviews should be very clear.

7.3.4 Health and safety issues

Health and safety issues link closely with working conditions, but because this aspect is often a separate area of concern in certification systems, it is dealt with separately. See Table 7-7.

Table 7-7: Overview of indicators regarding health and safety issues identified by the case studies

4	Indicators health and safety issues	Qn/Ql	Measurement method
	Background indicators		
-	Average number of people per health facility (national, regional, local)		Statistics
-	Average number of people per doctor		statistics
4.1	Number of workers reporting health concerns related to agrochemical use	Qn	Company/health clinic records and interviews
4.2	Level of compliance with a given standard for waste treatment and disposal	Ql	Company records
4.3	Number of accidents during work, as proportional to the total number of workers	Qn	National/regional: statistics Local level: company records
4.4	Number of deaths during work, as proportional to the total number of workers	Qn	National/regional: statistics Local level: company records
4.5	Number of retirements due to working accidents, as proportional to the total number of workers	Qn	National/regional: statistics Local level: company records
4.6	Benefits for disability and fatalities	Qn	Interviews and documentation
4.7	Health and safety policies	Ql	Company documentation and interviews
4.8	Noise above legal threshold	Qn	Company records, permit related documentation and interviews
4.9	Risk of fire outbreak	Ql	Company records, permit related documentation and interviews
4.10	Risk of gas emissions	Ql	Company records, permit related documentation and interviews

4.11	Number of staff with medical insurance	Qn	National level: statistics Local: Company records and interviews
4.12*	Investment in health facilities by bioenergy company	Qn/Ql	Company records and interviews
4.13*	Change in access to health care	Qn/Ql	Company records and interviews

Quantitative (Qn) or Qualitative (Ql). *: see also Working conditions indicator

The main health issues are accidents and occupational diseases. The most severe indicators are deaths and retirement due to labour accidents or labour related diseases. Other indicators are related to potential causes of long term health effects: like noise and dust emission levels etc. However, whether preventive health policies are in place or not, can be checked and can be regarded as an important indicator. National labour laws sometimes cover these aspects, monitoring and control could be an issue.

In Argentina, the health and quality conditions are monitored for the entire agricultural sector (primary and processed products) by SENASA (national service for health and quality of agricultural products) (Regunaga 2009). According to Regunaga (2009), Argentina has a given high priority to high quality and sanitary conditions in the grains and oilseeds production and trade sector since decades. Therefore in countries where national bodies have a good monitoring system, this area of concern is less critical.

In Brazil, statistics on accidents and deaths were available on sector level, enabling comparisons with other sectors. However, in other countries, these statistics are not available. On company level, it can be difficult to obtain accurate information from the involved companies, as the number of accidents of work related health issues is clearly not good advertisement.

Evaluation of indicators

Biomass supply in both the agricultural and forest sector has potential health risks. Many of the risks are already known, since biofuels/bioproducts are actually another application of a product of existing activities in the agricultural or forest sector. Since these risks are known and health and safety measures usually described in (national) law, it is possible to check compliance with these regulations, rather than to work out indicators in further detail. This way existing regulations are enforced. For relatively new feedstocks such as jatropha, health issues are not yet known which makes monitoring difficult.

Definitions should be better explained, for instance there is a big difference between bruises and fatalities. Furthermore, it is difficult to define a threshold for the number of accidents. The observation whether a company has a record system for accidents in place, is a (compliance) indicator of the companies awareness and attention for this issue and can be included in a certification system.

Another observation is that company records of accidents are sometimes absent. Health impacts that are related to environmental impacts, for instance due to air, soil and water pollution could be included as well.

7.3.5 Food security issues

Since biofuels and food are both produced on land there are inter-linkages between them. However, this trade-off is very complex and besides this there are many more factors that influence food production and availability than biofuel production alone (FAO 2010b; Achterbosch et al. 2013).

If food prices increase, accessibility of food to poor food buyers decreases. So any impact on food prices could change access to food. Overall inflation in a country has an impact on food prices as well. Countries that import fossil fuels will be impacted by changes in the oil price, production and local use of biofuels will ease price inflation and could therefore help to stabilize consumer purchasing power. Furthermore, biofuel production can offer opportunities to farmers to increase their income, thereby enabling them to buy (more) food (Achterbosch et al. 2013). These farmers then have to be included in the value chain. There may also be spill over effects to the rest of the economy due to biofuel production, such as to the transport and services sector, and indirect impacts on the overall productivity of agricultural production.

For three case study countries; Brazil (sugarcane), Argentina (soy) and Indonesia (palm oil), a quantitative analysis of the impacts of biofuel policies on food security has been made. The analysis is made by using a model to simulate the influence of bioenergy production in the countries. The model, a Computable General Equilibrium (CGE), called Modular Applied GeNeral Equilibrium Tool (MAGNET), analyses the effect of changes in trade and agricultural policies on international trade, production, consumption, prices and use of production factors. The food security indicators that are taken into account are; food availability, food prices, household income from farming and other labour and macroeconomic performance. The biofuel share in total transport fuels target of 10% for Indonesia, 25% for Brazil and 7% for Argentina are taken into account. A priori, an expansion in the demand for biofuels is expected to lead to increases in food prices. As land is a relatively scarce resource, the extra land required to increase crop production for biofuels comes at a higher price. For more information about the model see Achterbosch et al. (2013). In some agricultural systems an increase of production efficiencies in agriculture and livestock can uptake the additional demand, the relationships are very complex.

The indicative model runs show that the focus countries of the analysis (Brazil, Argentina and Indonesia) and several African regions, will expand land use and biofuel production in response to a strong demand on the world market, as simulated by ambitious targets for biofuel use in the largest economies of the world. The land use implications are substantial, although they rely heavily on the assumptions made in the model: Brazil produces ethanol six times beyond its local use). Its production expansion is based on an expansion of agricultural land use and on increasing productivity. In Brazil, Argentina and Indonesia the land use expansion is a factor 6, 3 and 2 higher respectively than required for an ambitious national biofuel target. The impact on land use expansion in Africa is also large as they start producing biomass for biofuels in the countries with a biofuel ambition. So, a global biofuels policy could contribute to upward pressure on land and food prices in several developing regions. But although global price and land use effects appear to preclude a negative evaluation on food security, there are several positive in-country effects that call for further specification and analysis (Achterbosch et al. 2013).

Apart from the model runs described above, there are also globally used indicators. Figure 7-3 shows the results for the indicator undernourishment for the case study countries. The data for this indicator is collected by FAO, and it is possible to classify countries on a global scale; Argentina and Canada have no undernourishment issues on a national level (they export food) while Mozambique and Tanzania have the highest prevalence of undernourishment, the remaining countries have (relative) minor issues on this indicator.

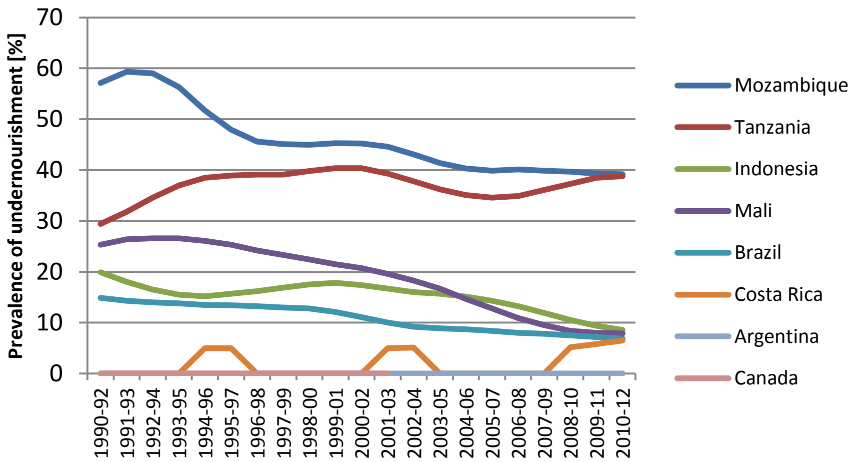


Figure 7-3: Results for indicator 'prevalence of undernourishment' based on (FAOSTAT 2012)

Table 7-8 shows the indicators on food security that are identified, and Table B18 in Appendix B provides the values for the case studies.

Table 7-8: Overview of food security related indicators as identified by the case studies

#	Indicator decription	Ql/Qn	Measurement method	National	Regional	Local
5	**Food security**					
	Background					
-	Food security index score	Qn	Statistics	•	•	
-	Population that is food insecure	Qn	Statistics and literature	•	•	
-	Poverty rates	Qn	Statistics	•	•	
-	% of household income spent on food	Qn	Statistics			•
-	Prevalence of undernourishment [%]	Qn	Statistics	•	•	
-	Calories per capita	Qn	Statistics	•	•	
-	Staple crop production (and price development)	Qn	Interviews/surveys	•	•	
-	Main regional staple crop production	Qn	Statistics	•		
-	Quantity and type of food that is lacking in the local community	Ql	Interviews/surveys			•
	Impact indicators					

5.1	Protection programmes available	Ql	Interviews			•
5.2	Providing alternative for current practices	Ql	Literature			
5.3	Number of people that became food insecure due to bioenergy production	Qn	Interviews/surveys and statistics	•	•	•
5.4	Previous land use of bioenergy crop area	Qn	Literature	•	•	•
5.5	Change in access to food due to bioenergy	Qn	Interviews			•
5.6	Conversion rates of food producing land due to bioenergy	Qn	Interviews/surveys and statistics	•	•	•
5.7	Perceived change in food security	Ql	Interviews/surveys			•
5.8	Δ in household income spent on food	Qn	Interviews/surveys			•
5.9	Δ in average time spend on food production	Qn	Interviews/surveys			•

Qn: Quantitative
Ql: Qualitative

Data on national production, yields and prices of main staple crops are available for most years. However different sources show contradicting results. Besides this, the data on regional production, yields and prices is very limited, especially in for example Mozambique. The main issues are that either the data is not available at all, has many gaps and is old and outdated (e.g. in the case of Mozambique). Regarding accuracy it is difficult to establish the impact that bioenergy projects have on food security. Changes in food availability and prices do not necessarily link to bioenergy impacts, but nevertheless these are good indicators because a downward trend could be reversed, e.g. by implementing protection programmes or putting more effort in education and training of farmers. This should only be required if food security is an issue in the area.

Evaluation of indicators

Food security is closely linked to poverty rates. The indicator 'food security index score' takes four different categories into account; affordability, availability and quality and safety into account (GFSI 2013). However, not many governments collect the data for this indicator. Most of the indicators depend on (available) statistical data. Together with other indicators that are applied in the case studies, such as undernourishment data, they can provide information on the status of food security in a country. Only if there is a food deficit in the country or region where the bioenergy is produced, the issue is relevant, and more detailed indicators should then be applied. The qualitative indicators such as protection programmes that are implemented by bioenergy projects can be used for this purpose.

Household level food expenditures data can be obtained by interviews. If this is repeated, it will become a performance indicator and in an area with biofuel development, part of this effect could possibly be linked to biofuel activities. Other performance indicators that can provide more information on the development of for example a region is the yield developments of the 5 main staple crops (GBEP 2011).

The more qualitative indicator of food security perception (whether people think their food security has changed), can be addressed by interviews or by surveys. The obtained data has to cover the period before the start of the projects and after implementation. This means that if projects existed for a longer period, the reliability of answers will be lower, which affects accuracy. And as the indicator already states, it concerns a perception and not hard data, but can be used to highlight potential problems. Bioenergy projects can provide data on previous land-use, and this can be cross-checked by local authorities, such as the district administration and at local communities. The accuracy of the indicator depends on the reliability of the data source, which in the case of local communities is often based on memory of the village-elders, and therefore not very reliable. This is similar for household expenditures and competition for labour. People from local communities are asked about their household expenditures and working hours with an emphasis on the change before and after implementation. For household expenditures on food, other influences such as a bad harvest due to drought can also interfere with food prices and is sometimes not recollected.

7.3.6 Land use competition and conflicts

There are 17 indicators identified on land use competition and conflicts by the case studies, see Table 7-9 below and Table B19 in Appendix B which includes the data for the case studies.

Table 7-9: Overview of land right related indicators as identified by the case studies

#	Indicator description	Ql Qn	Measurement method	National	Regional	Local
6	**Land use competition and conflicts**					
	Backgroundindicator					
-	Framework of land rights in the country	Ql	Literature	•		
6.1	The extent to which land acquisition followed the correct legal process	Ql	Company records and community interviews			•

6.2	The extent to which community land rights are determined and mapped	Ql	Company records and community interviews			•
6.3	The extent to which the principles of FPIC[a] are followed in dealings with local communities and indigenous peoples, including when handling disputes	Ql	Company records and community interviews			•
6.4	Number of conflicts due to biofuels expansion (and reason why)	Qn / Ql	National statistics	•	•	•
6.5	Expansion area over other cops	Qn	National statistics, interviews	•	•	•
6.6	Coefficient of expansion area of the crop vs other sector (livestock)	Qn	National statistics	•		
6.7	Compensation payments	Qn	Company records and community interviews			•
6.8	Language of contracts	Ql	Company records and community interviews			•
6.9	Availability of documentation for local communities	Ql	Company records and community interviews			•
6.10	Lost rights to land	Qn	Interviews	•	•	
6.11	Coherent land ownership structure	Ql	Literature	•		
6.12	Availability of treaties on land use issues with local stakeholders	Ql	Interviews			•
6.13	Hectares of land suitable for bioenergy production	Qn	National statistics	•	•	
6.14	Hectares under public land (communal) in total or as part of total land cultivated by bioenergy company	Qn	National statistics	•	•	•
6.15	Hectares under bioenergy cultivation	Qn	National statistics, interviews	•	•	•
6.16	Increase or decrease in land prices	Qn	National statistics	•	•	
6.17	Area under bioenergy production as percentage of total planted area	Qn	National statistics	•		

Qn: Quantitative

Ql: Qualitative

[a]: Free, prior and informed consent

In Argentina there is a negative correlation between the area of soy that is planted and the number of cattle in the livestock sector, see Figure 7B-5 in Appendix B. This implies that the expansion of soy took place on land that was traditionally farming area. The same correlation may also be observed in other regions such as for example in Brazil.

In Mozambique a broader array in compensation payments was found than only financial compensation. Also, material and physical compensation and community development and job creation was in some cases considered as compensation.

For most of the indicators no data was obtained, which shows the often problematic record keeping on this subject. In none of the case studies, data on the extent to which FPIC are followed in dealings with local communities was available, hardly on compensation payments, and none on lost rights to land. What is striking, is that problems can occur after a bioenergy project ceases its activities and people lose access to land as well as jobs, and this has occurred in Tanzania and Mozambique.

Evaluation of indicators

Many indicators are identified, and many are considered important. Some of the data for the indicators can be obtained from national statistics, such as the development of land prices and total cultivation area of bioenergy (relative to total area available, for example). Other indicators are more qualitative such as lost rights to land (difficult to quantify because the secondary land users are often not involved in land consultations) and the extent to which land acquisition followed the correct legal process. The data for these last two indicators have to be obtained from interviews with various stakeholders. The perception of the local communities is important. Free, prior and informed consent is crucial for the communities, but due to weak institutional frameworks, land deals are almost without exception complex (Vermeulen and Cotula 2010b). Checking compensation payment agreements, language of contracts and the availability of documentation for local communities (in their own language) are ways to check informed consent. Through interviews with various stakeholders (communities, government, NGO's), information can be obtained on how the process was executed. If there are national bodies that keep data on land conflicts (such as in Brazil), this could enhance data collection. Communities are often satisfied to see development in their area, however they should be compensated for any loss of land access. Checking whether there is any provision for returning land access rights in case of bankruptcy could reduce the risk of losing land access without compensation after projects discontinue.

More emphasis on alternative ways of compensation next to monetary compensation will be useful. A change in access to land is not always relevant, since secondary land users are not always involved e.g. if the land was previously privately owned or already used for bioenergy cultivation. This should be taken into account, by using background indicators. After establishing potential impact, more detailed indicators such as described above, can be applied. A significant number of people from the local communities would have to be interviewed, but this is generally limited to a small share of the community due to time and resource constraints. It is also difficult to establish who uses the land (secondary land users), they may for example only use the land once per year. More research would be required to identify secondary land users and potential impacts on this group.

Regarding accuracy, it is possible to cross check data through the multiple data sources. Data can be acquired at three different sources; at the local authorities (district administration), at the project management and at the local community. However, data on the land acquisition process has to be gathered at project-level, because often national data on land acquisitions does not exist. In addition, agreements with communities are very often not documented, but are made by verbal agreements.

It is important to properly define 'complied with' and 'socially accepted procedure' because there is too much room for different interpretations.

7.3.7 Gender issues

Table 7-10 below shows which indicators were identified related to gender issues (see Table B20 in Appendix B for the values). Some jobs attract more men while other jobs attract more women, so an unequal distribution does not necessarily show gender discrimination. Equal opportunities, salaries, and respecting the women's reproductive rights are regarded important indicators.

Table 7-10: Overview of gender related indicators identified by the case studies

	Gender related indicators	Qn Ql	Measurement method	National	Regional	Local
	Background indicators					
-	Gender-related Development Index (GDI)	Qn	GDI can also be expressed % of HDI. Statistics	•	•	
-	Gender Empowerment Measure (GEM)[a]	Qn	Statistics	•	•	
-	Right of land ownership for women	Ql	National law and interviews	•		
-	Benefits distribution between men and women in the family	Qn	Interviews			•
-	Female unemployment rate compared to average unemployment	Qn	Statistics	•	•	
-	Labour employment gap between men and women	Qn	Statistics, literature	•	•	

-	Presence of organizations for women’s rights	Qn	Interviews, internet	•	•	
7.1	Women's wages compared to men’s (doing work judged objectively to be similar)	Qn	Local: Company records and interviews Regional/national: statistics	•	•	•
7.2	The extent to which equal opportunities are extended to women and men in the workplace	Ql	Company records and interviews			•
7.3	The extent to which women’s reproductive rights are respected	Ql	Company records and interviews			•
7.4	Participation of women (in a type of job, company or sector)	Qn	Local: Company records and interviews Regional/national: statistics	•	•	•
7.5	Women participation policies	Ql	Company records and interviews			•
7.6	Contribution of bioenergy project to gender equality	Ql	Interviews			•
7.7	Benefits created for women	Ql	Interviews, company records			•

[a]: combines inequalities in (1) political participation and decision making; (2) economic participation and decision making, and (3) power over economic resources. Result: ranking compared to other countries.

Quantitative (Qn) or Qualitative (Ql)

Possible gender problems that can be associated with the production of liquid biofuels in general are often due to the lack of access to resources for women. Land ownership is often more difficult for women, and related to this, access to credit, because women do not have land that they can offer as collateral. Furthermore, if energy crops are planted on marginal land, this has a greater risk of pushing out women, since they are mostly the ones who collect commodities such as firewood from these grounds (Rossi and Lambrou 2008).

The participation of women in a certain company can be determined relatively easily. However, the indicator result is only informative not normative. Other issues like women’s wages as % of men’s work are sometimes hard to quantify on company level. However, even in countries like Canada there is a wage gap. Interviews executed for the Indonesian case study, clearly showed that in physical plantation work, the heavy work done by men, that women cannot perform physically, was paid better than the “light work” done by women. Also participation of females, working for free in the family plantation was observed. In Tanzania, women cannot be owner of land, but have rights to plant and harvest jatropha on part of this land.

Evaluation of indicators

On national level gender-specific indicators have been developed, like the Gender-related Development Index (GDI) (similar to HDI) and Gender Empowerment

Measure. However, it is difficult to quantify gender issues related to wage levels on company level as the jobs are not always equal. Furthermore, it is observed that while it is difficult to quantify gender issues on local level, obvious gender issues can easily be described in a qualitative way. Other gender related issues, like discrimination and sexual harassment, should be addressed on company level with specific indicators. It is important to note that the problems related to gender are not exclusively linked to the bioenergy sector.

7.4 Discussion

Socio-economic indicators and areas of concern

This analysis and review focused on socio-economic indicators, but for a comprehensive overview, environmental indicators on topics such as water, biodiversity, GHG emissions etc. should also be taken into account, and these can be inter-linked. A reduction in water availability or biodiversity, for example, influences socio-economic circumstances. Furthermore, additional research into the interdependency of indicators is recommended. Food security for example is related to the degree of economic development of a certain society, rather than its ability to produce food (see e.g. Achterbosch et al. (2013).

Some indicators can be applied to more than one area of concern. Job creation for example can be part of employment generation, rural and social development and economic feasibility. Therefore some data serves similar indicators for different areas of concern. It is possible to create one area of concern that includes economic and local prosperity, e.g. ‘contribution to local economy’. But we analysed them separately since a major focus was economic sustainability. Similarly, working conditions and health and safety impacts are closely related and could also be combined in one area of concern but are analysed separately. For other purposes, the division of the areas of concern may be changed.

Methodology of data collection

The different case studies showed that the level of detail of the collected data was different. This is partly due to various time constraints, but also to the level of willingness to cooperate by the selected companies and government institutions that could provide data. While this is also a constraint if the indicators are applied in certification systems, the willingness of companies and projects to participate may be higher in such a situation.

Being able to measure the impact of a standard or a regulation over time is essential. This is done to evaluate the completion of the initial objectives of the standard/regulation. But also to improve the implementation of the standard/regulation, based on lessons learned and data collection. However, in this study, it was not possible to repeat measurements.

Data quality is sometimes problematic, which is also acknowledged by the UN (2011) and efforts are made to try and improve rural development statistics. Since national statistics that are based on different sources (or even the same sources) show different values, for example FAOSTAT and COUNTRYSTAT, and because it is unclear which one is the most accurate or reliable one, it is important to apply multiple datasets, and reference the data correctly.

Quantitative data may be preferred over qualitative data. But qualitative data can emphasize aspects that are important, such as people's opinions on food security, that are hard to quantify. Qualitative data can be gathered at communities, and by talking to employees. However, a reasonable number of people should be interviewed to obtain significant results. Due to time constraints the number of interviews was limited in the case studies.

The multitude of languages in developing countries makes data collection complex. Translators assisted in data collection, but it cannot be excluded that they sometimes influenced the results. There were some misunderstandings in data collection, due to the complexity of the questions, cultural differences and the lack of written notes. For example, yield per ha had to be changed to yield per acre in Mozambique and Tanzania, furthermore farmers in Mozambique were often not able to recollect how much time they spent the past year on the cultivation of jatropha.

Implementation in certification systems

Standard setting and the development of legislation are a continuous process and should allow for lessons learned as well as for the incorporation of experience and progress in state-of-science to improve sustainability requirements and their implementation.

There are several (voluntary) certification systems that include socio-economic aspects. They sometimes require impact assessments, for which general socio-economic data has to be collected. The RSB Standard (RSB 2010) for instance, requires an impact assessment (ESIA) to be performed by all operators. However, not all biofuel standards require these impact assessments. There are also standards and certification systems which are not specific for biofuels (e.g. Forest Stewardship Council, Rainforest Alliance, Social Accountability International), but which can be used to demonstrate compliance with socio-economic requirements in the context of sustainable biomass, bioenergy or biofuel supply chains.

Implementing socio-economic indicators in a certification system would require an adequate monitoring and control system. There are not many certification systems available that can include individual smallholders. An attempt to apply a group certification under the Dutch NTA8080 system for example, proved very problematic (Romijn et al. 2013). They experienced a lack of capacity to analyse soil, water and air samples in the country of study, Tanzania and faced other complexities that the certification system could not cope with such as the fact that smallholders do not have a physical address. Also, the NTA8080 requirements listed that a homogenous cooperation should be formed in terms of soil type, agricultural practices and climatic conditions, while in reality big differences occur even within the same region (Romijn et al. 2013).

Indicators can be used in monitoring to examine trends, and in identifying challenges, which may require additional resources. However, indicators and indices[27] are only useful, regardless of how carefully chosen, in describing or helping to describe a situation. They do not offer an explanation for the reason why that situation exist (Diaz-Chavez et al. 2012).

7.5 Conclusions and recommendations

Socio-economic indicators were applied to eight case study countries and evaluated on accuracy and practicability. Per area of concern, impact indicators are compiled that are most relevant for bioenergy projects, see Table 7-11.

Economic feasibility, the impact on local prosperity, labour and working conditions, food security and land ownership and rights, are important socio-economic areas of concern that can assist to evaluate local socio-economic impacts of bioenergy projects in developing countries. The impact on local prosperity can be assessed by

[27] An index or an aggregated indicator combines values which are expressed as a single value

analyzing the impact of the bioenergy system on; employment figures (with a differentiation between permanent and temporary contracts), by measuring community investments by companies, improved access to energy, by checking wages and employment benefits, maximum working hours and freedom of association and the provision of personal protective equipment (for permanent and temporary workers). Furthermore, food security that is impacted by bioenergy companies can be assessed by measuring: land that is converted from staple crops, (perceived) food availability changes, changes in time spent on subsistence agriculture, and employment and wages. Land rights issues can be measured by checking whether the company has a legal (unchallenged) title, which area of land is customary, public or community land, which area of land that is currently under dispute. Furthermore, the (possible) investments made by bioenergy projects in the region, for example in health care, education facilities, infrastructure etc, can be evaluated and should be taken into account. But not all investment remains in the country; especially when large proportions of the required technologies, equipment and human capital have to be imported, the net short-term effect on the GDP of a country will be lower. However, bioenergy investments can also be a stepping stone for increased development of the region in the longer term. Further development of indicators to measure more subjective social well-being aspects in a systematic way is recommended.

Both positive and negative socio-economic impacts are closely linked to company practices, in combination with the regulatory and institutional context. Impacts on a local level are often not visible at an aggregated national level, especially if the sector is not fully developed yet which is the case for some feedstocks and countries in the bioenergy sector studied here. A clear example of this are the economic indicators; the companies that have only started to produce biofuel recently are not reflected in national GDPs. The opposite is also true; local negative impacts such as the number of people that have lost land rights could be offset by the total national employment that has been generated. Some feedstocks such as soy are produced in complex and well developed agroindustry chains and therefore specific impacts of biofuel production are hard to separate. Furthermore, regional differences in socio-economic circumstances are large, and hence, the impact of bioenergy projects. Therefore it is essential to look at impacts on different levels; national, regional and local.

Background indicators, such as the GDP and the level of unemployment in a region, do not link directly to impacts of bioenergy, but can provide a ‘snapshot’ of the relative development of a region or country in which bioenergy projects operate.

They can help identify potential important areas of concern (associated with negative or positive impacts) beforehand, such as food security or gender issues. In this way, they can help to determine whether the area of concern, e.g. food security, is an important issue to consider in the project region. After this superficial check, more detailed indicators can be applied, if necessary, to give insight in the extent and the exact nature of the potential (local) impact. This means a staged approach is recommended (1) scan for each chosen area of concern, (2) in depth research in those specific areas of concern in which risks were identified during step 1. Working conditions in Argentina for example are well monitored and regulated by law, but this is much less the case in Tanzania. Thresholds have to be determined, but benchmarking the local situation to global averages would provide a first starting point. For an example of an ex-ante analysis for two regions in Mozambique, see Van der Hilst et al. (2013).

Economic feasibility of projects is not an issue in current certification schemes. However, especially projects that use feedstocks for which relatively little commercial experience exist (Jatropha, ligno cellulose), the risk of bankruptcy is relatively high, and this has a mayor negative (socio-economic) impacts on the local population (Van Eijck et al. 2014). Including more economic indicators may help to reduce the number of disrupted projects.

Methodologies should preferably be based on quantitative data. Many indicators are currently based on qualitative data, which is sufficient for themes such as working conditions, health issues and land use conflicts. But other, more complex, themes such as food security, land competition or economic development of e.g. a region, that link with many different factors, need more comprehensive methodologies such as Input/output analyses or General Equilibrium models. Further development of these models is recommended.

Availability and reliability of data is a concern. Most economic indicators are based on robust methodologies, but accurate data is often lacking and therefore it is hard to use the subsequent indicators effectively. National statistics are unreliable; poorly available, often outdated or inaccurate in most developing countries. Government bodies or international organisations could collect and monitor the data which would provide for example the basic data for the background indicators. Collaborations with the private sector, especially in countries where statistics are still lagging behind could be considered. More data collection is required on all levels (national, regional and local).The global datasets should be improved in terms of accuracy, spatial resolution, consistency, classification, ground-truthing, updating and continuation. Therefore it is recommended that international organisations contribute to better data availability including statistical data on socio-economic conditions on local, regional and national levels. Additional socio-economic data is required on economic aspects such as regional GDP and Input/Output tables, on employment and local prosperity aspects such as total workforce and (un)employment, education levels and access to electricity, on food security aspects such as regional food security indices, and on land aspects such as spatially explicit zoning maps and community land access.

The trade-off between the accuracy of the indicators and the practicability (easiness of data collection) varies per country and per feedstock. The more experience with a feedstock in a country exists, the more data is available. For relatively new feedstocks the underlying assumptions in the economic feasibility studies should also be provided, this makes it possible to review the assumptions with the latest data. In addition a sensitivity analysis should be executed to provide more insight in the variables that have a large effect on profitability. For relatively new feedstocks and for feedstocks for which the production country has little experience, those variables should be analysed and their range included in NPV calculations. There are several aspects that can contribute to a better accuracy of indicators.

- First, it is necessary to utilize stricter definitions of methodologies, e.g. the minimum number of respondents in a survey should be listed.
- Second, data formats should be as clear as possible with no room for different interpretations. This to ensure that the respondents comprehend the requested data.
- The number and type of respondents can also be improved. There are different stakeholders involved in the value chain; local communities, employees, government and non-governmental organizations, etc. It is important to identify which data has to be collected from which stakeholder(s). Joint efforts between the private sector and the government are necessary to initiate a monitoring programme where these indicators can be followed in time. These have to be tailored to national and local circumstances.
- Moreover, a more uniform use of units throughout the data collection diminishes the chance on error and thus improves accuracy.
- Finally, some data, such as financial projections, can be based on wrong assumptions such as unrealistically high yields, which leads to unreliable

results. The assumptions or evidence on which the indicator is based should therefore also be provided.

Recommendations for governments:

This chapter clearly indicates that inclusion of socio-economic aspects in sustainability frameworks for bioenergy is desirable. Not only to avoid that the benefits for climate change and global energy security are being offset by detrimental effects on local communities and livelihoods, but also to stimulate that the potential socio-economic benefits of (sustainable) bioenergy schemes are maximized. The bioenergy sector is closely linked to the agricultural sector and policies that support sustainable bioenergy should cover the agricultural sector at large. The synergies of the different sectors involved in bioenergy should also be considered, including the energy, agricultural, transport, industrial and environmental sector. Key is that better management of agriculture can avoid displacement of food production by biofuels due to higher efficiency. Generally, this leads to increased and diversified incomes in rural economies. Certification could act as a tool to improve the overall management of the agricultural sector. National policies in particular can play a role in deploying sustainability criteria (for the whole agricultural sector), in improved monitoring on various socio-economic aspects such as food security, preferably on a regional scale (in the developing countries themselves), in implementing pilot projects and by showing long-term commitment to these projects. Real and sustained field experience from pilot projects is important to obtain best practice experience and reduce future risk for the (future) bioenergy producers.

Governments can also participate in and commit to international sustainability initiatives and frameworks such as RSB (private initiative) and GBEP (governmental initiative)Furthermore, proper land use planning including tangible zoning can play an important role to assess and steer land requirements.

Capacity building in rural areas is required. Governments should asses and select business proposals and investment plans based on clear sustainability principles, provide accurate statistics and maps, and design and implement a biofuel or biobased economy policy that will help to prevent displacement (of food and people). Targeting joint development and synergy with the agricultural sector is essential. Finally, balanced legislation that avoids negative impacts and at the same time allows sufficient freedom for the development of the market is required.

Acknowledgements

This chapter 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 in the Seventh Framework Programme for Research and Technological Development (FP7). The case study on Mozambique was funded by NL Agency through the Jatropha data collection project under the Global Sustainable Biomass fund. We would like to thank all Global-Bio-Pact partners and case study companies for their inputs in time and effort. Furthermore we would like to thank Martijn Vis and Jinke van Dam for their contributions to earlier reports this study was based on, Carmen Heinze from NL Agency, and Thom Achterbosch (LEI) who analysed food security in the Global-Bio-pact framework. This chapter was partly compiled while the corresponding author was in residence at Imperial College London.

Table 7-11: Summary of positively evaluated socio-economic indicators

nr	Impact	indicator	Measurement / monitoring /units	Guidance
1	Economic feasibility	Production cost	Breakdown of yearly production costs of the facility (incl. labour, raw material, energy, services etc.) EUR/t of feedstock)	Annual production costs within a 5-year period
		NPV or IRR	Should be positive	
2		Value added	Value added by the operation. Annual value of sales less the price of goods, raw materials (including energy) and services purchased (EUR/t of feedstock)	Annual value added within a 5-year period
3		Taxes/royalties paid to the government	Breakdown of payments made to the government per year (EUR)	Payments made to the government per year within 5 years
4		Contributions made by the operation to allied industries in the local economy	Percentage of total production costs paid to contractors, suppliers per annum	Percentage of total production cost paid annually to contractors and suppliers of raw materials (excluding suppliers of feedstock) within a 5 year period.
5		Production farmed by smallholders or suppliers	% of feedstock that originates from associated smallholders and outgrowers	Percentage of feedstock that originates from associated smallholders outgrowers within a 5-year period. Number of associated smallholders or outgrowers.
6		Amount paid to smallholders and suppliers of feedstock	Annual amount paid to smallholders and suppliers of feedstock (EUR)	Annual value paid to associated smallholders and outgrowers per unit of product within a 5 year period.
7	Employment, rural and social development (local prosperity, local well-being)	Employment	Total number of employees and person days of employment per year	Total number of people employed each year and total number of person days per year within a 5 year period. Breakdown should be given for categories of employment for operation (management/office processor/field labour, male/female, contract/no contract.
8		Ration between local and migrant workers	Ratio of employment from local area / outside local area per category of employment (management/office/processor/field labour)	Local area is defined as state or province.
9		Percentage of permanent workers	Percentage of workers that have a fixed contract, employment per category of employment	

10		Provision of worker training	Number of workers that have received training (for skills development, education etc.) each year, number of working days spent in training provided by the operation each year, type of training	
11		Community investment	Amount invested in community investment projects (e.g. CSR) (% of annual revenue) and qualitative description of investments including any projects specific for women	
		Improved access to energy		
		Employee income		
12	Working conditions and rights	Employee income	Average income of employees by category of employment (EUR)	
13		Employment benefits	Employment benefits (e.g. housing, health care, holidays) provided by operation (description of benefits per employee per year)	
15		Hours of work	Average daily hours of work per employee per employment category (h)	
16		Freedom of association	Existence of labour unions	
17	Health and safety	Work related accidents and diseases	Number of work related accidents per person days of employment per year, number of work related diseases/person days of employment per year	
18		Personal protective equipment	Percentage of permanent and temporary workers that uses appropriate personal protective equipment.	
19		OSH training	Percentage of employees that have received OSH training	Training records and worker interviews
20	Food security	Land that is converted from staple crops	Land that has been converted from staple crops (ha)	
21		Edible feedstock diverted from food chain to bioenergy	Amount of edible raw material diverted into bioenergy production (t)	
22		Availability of food	Perceived change in availability of food after the beginning of bioenergy operations	
23		Time spent on subsistence agriculture	Change in time spent in subsistence agriculture in the household.	

24	Land rights	Land rights and conflicts	Operation has legal title/concession for the land that is not challenged	
25			Area of land cultivated by the operation that is customary, public or community land (ha)	
26			Area of land currently under dispute, land conflict, if so, what caused them, how were they resolved?	
27	Gender	Benefits created for women	Employment benefits that are specific for women	List any employment benefits that are specific for women (i.e. maternity leave, others)

7.6 Appendices to Chapter 7

7.6.1 Appendix A: feedstock and country specific aspects

Feedstock specific aspects

Soy

- *Annual crop*
- *Largely mechanised*
- *Food crop with by-product biofuel*

Soy is an annual crop that can be produced for food or feed and as by-product for biofuel. The soybeans are crushed into soy meal (mainly used as animal feed) and soybean oil. The oil is usually filtered in a pre-treatment step to remove water and other contaminants. The soybean oil is then further processed into biodiesel by a transesterification step, where the oil is blended with an alcohol (usually methanol) and a catalyst. The oil molecules are broken and reformed into esters (biodiesel) and glycerine (van Dam et al. 2009a).

Palm oil

- *Perennial crop*
- *After harvest Fresh Fruit Bunches need to be processed within 24-48 hours.*

After planting, young palm trees take 30-36 months to produce their first harvestable FFBs, and yield their peak harvest from years 8-15. The oil palm’s economically viable life span is typically 22-25 years, although this can be extended for as long as 30 years, after which the old stand requires replanting(USDA - FAS 2007). Palm oil is used for various purposes such as food, cosmetics, biofuel etc. Palm oil is obtained by processing Fresh Fruit Bunches (FFB) of oil palms, thereby obtaining crude palm oil (CPO) and palm cake. Harvesting of FFBs in Indonesia is done manually. From the field, FFBs are transported to the palm oil mill for processing. Around 24 hours after harvesting the FFBs begin to degrade in quality, so palm oil mills are situated on or in the vicinity of the plantations. In the palm oil mill, bunches undergo sterilizing and threshing to free the palm fruit, mashing of the fruit and pressing out of the crude palm oil. The crude oil is further treated to purify it for storage and export. The fruit kernels are also separately processed into palm kernel oil (PKO); a process that may take place in the same mills or elsewhere. One tonne of FFB yield approximately 0.21 tonne CPO and 0.05 tonne PKO (World Bank 2010a). The by products are shells and fibres and palm oil mill effluent (POME) which can be used as energy source or fertilizer. See also (Wicke et al. 2008).

Jatropha

- *Non edible perennial*
- *Relatively new crop in commercial farming*
- *Low value of the seeds, so high volumes required*
- *Harvesting up to now only possible manually*

Jatropha is a non-edible perennial crop that does not require a lot of maintenance and can grow on marginal to fertile land. It produces seeds once or more times per year and can be planted as fence or in a plantation (Van Eijck et al. 2012). Jatropha Straight Vegetable Oil (SVO) is obtained by crushing jatropha seeds, or by using chemical extraction. The by-product is seedcake. The SVO can be further processed by transesterification into biodiesel. Jatropha SVO or biodiesel can be used as diesel substitute in cars but also to power presses, grain mills and electricity generators in rural areas. Seedcake can (amongst others) be used as fertiliser, in biogas digesters to generate biogas for cooking or as substitute for wood fuel.

The jatropha sector is still in its infancy stage, yields are currently far lower than what is theoretically possible due to the low level of knowledge of the crop(Van Eijck et al. 2014). Due to the low value of jatropha seeds and the infancy stage of the sector, the value of the sector is not reflected in macro-economic (national) indicators yet. The majority of employment is required for harvesting which is seasonal. The (labour) time that is available by smallholder farmers during the peak season for staple crops or other cash crops can compete with maintaining jatropha. However, in an intercropping system, the devoted time and inputs to the food and cash crops benefit jatropha as well. The long term health effects of jatropha are unknown.

Sugarcane

- *Ratoon crop with harvest every year, replanting after 5 years*
- *Harvesting can be done manually (heavy labour, burning cane is necessary) or mechanically*

Sugarcane is a ratoon crop, with typically 5-year rotations and is grown in tropical climates. Ethanol can be produced complementary to sugar (if obtained from molasses) or in just stand-alone mills. Ethanol from sugarcane is obtained by distilling sugarcane juice (or molasses), this process also provides bagasse, for further description of the technology see Van den Wall Bake et al. (2009).

Sugarcane can be harvested manually or mechanically. Labour conditions for manual sugarcane harvesting are harsh due to: exposure to heat and sun, smoke and particle emissions due to burning of sugarcane, heavy loads during harvesting. In the conversion plants the atmosphere is hot and noisy with strong sugary odours (sugar production) while the distillery (ethanol production) is fresher and quieter. See also(Herreras Martínez et al. 2013b).

Lignocellulosic biomass (wood)/ forestry

- *Perennial crop, relatively long period before harvest*
- *The harvested wood can be used for several purposes, amongst others paper and pulp.*

Lignocellulosic biomass can be sources from various tree species, e.g. pine or eucaluptus. The wood can be converted into oil by various processes, e.g. a pyrolysis or the Alcell technology (developed by Lignol) whereby cellulose is converted to ethanol to obtain bio refined ethanol, pure lignin and other co-products. The forest sector is traditionally relatively dangerous. Other markets for this sector are the pulp and paper industry.

Soy oil processing

The process begins with the reception of the soybean grains (from the feedstock production owned by the company or by third parties which arrives to the plant either by truck or rail. The grains are unloaded thru unloading platforms and are taken into pre-cleaning where the soybean grains are separated from the dust of the field work. Once cleaned the grains are stocked in different locations (concrete silo or bags).

From the silos the grains are transported to the process plant where the industrial process begins. The first plant is the PREPARATION plant; the objective is to separate the husk from the grain and to laminate the latter into grain laminates. As a sub product the “husk pellets” are obtained and are loaded into trucks for sale. The soybean laminates are taken into a second process plant called EXTRACTION where they are covered with hexane in order to extract the oil laminate. This is when the soymeal is separated from the soybean oil. In this plant the soymeal is obtained as a sub product. The soymeal is transported into the soy cell where is stocked for later dispatch either by truck or train.

The oil extracted is pumped into the next plant, PRETREATMENT. This is where the oil is treated in order to get refined oil. For that purpose the oil is treated witch phosphoric acid and caustic soda with water. As a sub product the flock is obtained and stocked in tanks for the later unloading into trucks for sale. The refined oil is pumped into the last plant called TRANSESTERIFICATION where, thru methanol and sodium metoxide, the refined oil is turned into soy biodiesel and glycerin. Both are stocked in tanks for the later unloading into trucks and its sale.

Soy biodiesel process

The production process begins with a physical refinery process, for the removal of impurities e.g. proteins, gums, free fatty acids, oxidation compounds, and colour bodies and neutralizing the free fatty acids, reducing phosphorus contents and acidity. Acids (chloridic or phosphoric typically) are used to degum the base oil and remove any high free-fatty acids. The amount of acid needed depent on the incoming base oil; however, only a small amount (compared to alcohol and the catalyst) is used in the biodiesel process. Typically, the amount is less than 0.5% of the total biodiesel volume that is produced. The next step is centrifugation, this allows for de-gumming or the separation of gums and impurities. The next step is bleaching with silica adsorbents for removal of residual soaps after neutralization (”Trysil”). Neutralized oil is then mixed with methanol and sodium methylate (also called sodium methoxide) in trans esterification reactors.

The crude glycerine by-product is about 12 % of the biodiesel produced. The crude glycerine runs through the glycerine column to recover the un-reacted methanol. The methanol in the biodiesel is recovered and sent to the methanol column for clean-up prior to recycling back to the reactor. The produced glycerol was 85 % purity according to the HPLC analysis and could be used in industrial uses or exposed to further purification for pharmaceutical uses. Free fatty acids of 2 % of the oil weight are obtained, as well as sodium phosphate salts.

The biodiesel is washed with water at low pressure and in the next step water and solids are removed by the centrifuge, going from there to the dryer at low pressure and finally is piped to the storage tanks.

Some of the most important chemical and physical quality control parameters of the produced biodiesel are measured and compared with the petroleum diesel parameters. These parameters such as viscosity, flash point, pour point, cloud point, carbon residue, acid value and calorific value are continuously tested at the quality control laboratory, checking if them have acceptable values and are in agreement with the petroleum diesel parameters.

Water recovered during drying of the esters and glycerol fractions is recycled in part, going to activated sludge biological treatment plant at the facility. The wastewater characterization from biodiesel process is tested using techniques such as Chemical Oxygen Demand (COD), Total Organic Carbon (TOC) and gas chromatography for the measurement of methanol.

Country specific aspects and description

Argentina

Argentina is a large country with a total land area of 274 billion ha (World Bank 2013).

The soy sector in Argentina is one of the largest in the world (together with the USA, Brazil and China) with a production of over 50 million tonnes of soybeans and around 7 million tonnes soybean oil in 2010 (FAOSTAT 2012). The installed capacity for soy biodiesel is over 3 million tonnes/year in 2011 and in 2010 1.7 million tons soy biodiesel was produced (CADER 2012). Cultivation is done by large scale production systems, in different regions (Hilbert 2012; Diogo et al. in press). The key driver of biofuel markets in Argentina is economic development, especially through potential export markets such as the EU (Tomei and Upham 2009). In 2006, a law was approved (26.093/2006) that involves a regulatory and promotion regime for the sustainable production and consumption of biofuels. A tax exemption of 15 years can be provided under this law. At the same time a minimum blending ratio of 5% for biofuel with fossil fuel (petrol and diesel) was established for early 2010. Argentinean policies are further described by e.g. (Lamers et al. 2008; Hilbert et al. 2011; Hilbert 2012). The income for the country due to the taxation of the soy sector is huge, soy oil is taxed at 32% and biodiesel at 20% (17% net). The sector is highly mechanised and differences between companies are small. The key characteristics of the sector are:

- There is a seasonality in production while there is a steady demand, so the price of soy decreases during the harvest period and increases if stock depletes.
- Because of the seasonality, the soy processing factories close several months of the year.
- For ecological and profitability reasons the production of soy is concentrated in a small number of regions.
- Local prices of all intermediate products are freely defined by the different stakeholders
- Most of the production is export oriented which means that internal prices are highly influenced by international prices.
- Brokers are the link between the producers and the buyers of the production
- Soybean oil used for biodiesel is a co-product of soybean meal and generally there are difficulties to place it at international markets.

There has been a sharp increase in land prices and new models of land acquisition appear, such as investors that jointly purchase large plots of land. Land ownership is more and more separated from companies that use the land for production and companies that coordinate financial capital. The origin of the workers is not the same as where production takes place, migration is high during farming season. Argentina is a food exporting country with an overall capacity to feed 440 million people (2012) and imports different types of fuels from different countries. The government has a Universal Child Assignment Plan, which seeks to give a monthly sum of around 270 pesos (US$ 63) per child to working families under the poverty line.

Indonesia

The country has a total area of 189 Mha. There is a national strategy that includes a commitment to increase the contribution of renewable energy sources, which includes a target for biofuels of 5% by 2025 (Presidential Regulation No. 5/2006). However, progress has been limited so far(Simbolon 2009). The palm oil sector in Indonesia is the largest in the world (Malaysia is second) with a production of almost 20 million tonnes in 2010 (FAOSTAT 2012). Crude palm oil is the leading export commodity with a value of almost 7 billion $ (5 billion €) in 2007(World Bank 2010a). Production has expanded from around 3 million ha in 1997 to almost 8 million ha in 2010 (DG Estate Crops 2011). The average yield is around 2.7 tonnes CPO/ha(Sheil et al. 2009). Biodiesel production is still relatively low with approx. 400 million litres produced in 2010, although installed capacity is 10 times as much(USDA-FAS 2010).The 2009 implementation of RED in the EU has prevented biodiesel export to the EU. Different production systems exist; private plantation estates (50% of planted area), smallholder areas (41%) and state owned plantations (8%) (DG Estate Crops 2011). The plantations are often developed in conjunction with smallholders and outgrowers. There are large differences between regions that produce palm since a long time, and newly established production areas The majority of palm oil production is located in Sumatra and Kalimantan. Production in Sumatra is more profitable than in other regions.

A large portion of Indonesia's land (60%) is designated as forest zone, with 55 million ha as protection and conservation forest. There is a net loss of forest cover. The granting of palm oil concessions permits the concessionaire to clear fell areas of conversion forest. Harvesting and selling this timber (even on degraded land) provides an economic boon and means that plantation development is sometimes not followed through(van Gelder 2004; World Bank 2006). There is also a competition for suitable sites between the pulp sector and palm oil sector(World Bank 2006). Large number of people in rural areas have little or no land and there are high levels of inequality in the distribution of agricultural land. Land ownership structure (stemming from colonial system) has proved inflexible in responding to social changes. There is a lack of transparency and complexity and confusion surrounding the legal framework governing land rights(Winoto 2010). Also a lack of adequate legal recognition of customary rights to land. "light" work by women paid less than "heavy" work done by men. Labour force on plantations consists mainly of men. Key concerns are; freedom of association, use of child labour, occupational safety and health and discrimination(Situmorang 2010). Use of forced labour is less prevalent. The type of work varies from palm pickers, carrying sacks of palm fruits to carts, and pushing carts to a collection site. Work related accidents that have been reported are e.g. blinding by latex and resin. Smallholders work with herbicides and store chemicals while they displayed low awareness of associated risks.

Tanzania

The jatropha sector was created around 2005 in Tanzania, but is however still in infancy stage. A number of projects were active, around 2008 at the height of the peak there were around 30 (?) projects, but many of them have discontinued since then due to various reasons (see e.g. (Romijn and Caniels 2011). The production of jatropha oil in Tanzania is several ten thousands of litres per year. Some of it is used in the country in engines that have been modified, some is exported (test quantities). Different production systems exist; plantation, outgrower and smallholder (hedge) production systems. The policy is rather ambiguous, biofuel investments were welcomed by Tanzania early 2005 but new projects were halted until further notice around 2009 (Habib-Mintz 2010).

The reduced rights of casual workers compared to permanent workers are an issue. Tanzania is not food self-sufficient. Customary land rights are very common. Land issues were already occurring not related to biofuels, (Habib-Mintz 2010). Women are often not land owners, this is typically inherited via the male family line. Jatropha farmers are often subsistence farmers with little room for failures, increased income has to compensate for reduced time for food cultivation.

Mali

The main objective of the energy policy of Mali (adopted in 2006) is to contribute to sustainable development of the country. Furthermore they want to reduce the contribution of wood fuels in the total energy consumption from 81% in 2004 to 60% in 2015 and increase the share of renewable energy in electricity production from less than 1% in 2004 to 10% in 2015. They also want to develop a biofuels industry (incl. jatropha) for various uses(DNE 2007). The main policy instruments are suppression of import taxes and duties on renewable energy and energy efficiency equipment, and the provision of investment subsidies for rural electrification projects. The national biofuel strategy is to replace 20% of the diesel consumption with biofuels by 2020, jatropha oil is among the two crops that have been identified as most promising options (ANADEB; national agency for the development of biofuels). Jatropha based biofuel will exclusively be for the local market, directly or blended with fossil diesel. In Mali the two main production systems are decentralised and centralised community based approaches. There are no large scale plantations in operation. Cultivation is performed by local farmers in living fences (hedges) or intercropped on land areas of 1 to 5 ha. The harvested seeds are sold at local seed collection points. An estimated 20,000 km of jatropha fences have been planted from 1970 to 1996. Most projects are still in start-up phase and, due to the perennial characteristics of jatropha, no significant amount of oil is being processed yet. Around 6 to 7 projects are active (based on data in 2012).

Jatropha is often planted as fence in Mali, already since the 1980's. Mali is not food self-sufficient. Traditionally there is friction between farmers and nomads. Climate change is increasing the pressure on land and water resources which may aggravate tensions. Forests are being converted to agricultural land (and overexploited for wood fuels) therefore deforestation exists (and desertification). The land tenure system is complex, it recognizes both customary and modern land tenure laws. Customary law is oral, variable and mainly based on kinship, gerontocracy, seniority and gender and conflicts often with modern laws. Land is always owned by the government and can only be accessed by rental, allocation or grant. 68% of the farmers cultivate on 5 ha or less. Foreign direct investment from China, Lybia and South Africa cause displacement of farmers in the Niger delta (Baxter 2011a). The energy profile of Mali is characterised by an excessive exploitation of forestry resources and heavy reliance on fossil fuel imports. Jatropha farmers are often subsistence farmers with little room for failures, increased income has to compensate for reduced time for food cultivation

Mozambique

The government in Mozambique has created a big push for jatropha in 2008 when they requested all provinces should actively promote the cultivation of jatropha. There are various large scale companies (around 5 to 7) that are cultivating jatropha although many of them (around 3) have discontinued since around 2011. The largest plantation is around 2000 ha, one by the former SunBiofuels and one by Niquel. There are also a few larger scale projects that work with smallholders. The amount of jatropha oil produced so far is insignificant, there is no processing facility in Mozambique for jatropha that exceed a few thousand litres per year so far. Mozambique is not food self-sufficient. Jatropha farmers are often subsistence farmers with little room for failures, increased income has to compensate for reduced time for food cultivation

Brazil

The country has a total area of 842 Mha. The stimulating policy for bio-ethanol between 1975-1999 and the introduction of Flex Fuel Vehicles in 2003, have helped to increase ethanol production and demand (van den Wall Bake et al. 2009). For further policy descriptions see e.g. Van den Wall Bake et al. (2009). The sugarcane sector in Brazil is the largest in the world with a production of over 700 million tonnes sugarcane in 2010 (FAOSTAT 2012). The production of ethanol (both anhydrous and hydrated) reached over 25 billion litres in 2009 (BEN 2010). Brazil is also a very large ethanol consumer with a minimum of 20% ethanol blended in the fuel supply. Brazil also exports ethanol, around 3.3 billion litres in 2009 mainly to the US(ANP 2010). Different production systems exist;

plantation and outgrower or supplier production. The typical size of cultivation is between 1,000-6,000 ha (42% of independent suppliers) to 3,500 ha (0.5% of suppliers) (Orplana 2011). In 2010/2011 the bulk of sugarcane production (89%) occurred in the Centre South (CS) region and a smaller share in the Northeast (NE) (11%). The average yield is 77.8 t sugarcane/ha, while in the NE this is 55 t/ha. Sugarcane producers in the NE are entitled to a subsidy of 2.1 €/ton sugarcane up to 10,000 tons. In the CS the average industrial capacity is large, close to 2-3 million tonne sugarcane/year per mill. For a description of sugarcane production in NE, see e.g. Herreras Martínez et al.(2013b).

The sugarcane sector contributes significantly to GDP in Brazil. Legislation to allow only mechanised harvesting has a huge effect on employment (reduced). Due to the seasonal characteristics of sugarcane production, the number of 'end of contract' is very high (in the NE). There is also a very high percentage of informal jobs in the area (25%).

About 90% of Brazil's total food production is concentrated in southern Brazil while 60% of the food insecure population are located in the North and Northeast (FAOSTAT 2010). The production of soybeans in the Cerrado region (central) is said to have caused deforestation, and indirectly contributed to the deforestation in the south of the Amazon region (Walter 2009). The Brazilian government has commissioned an 'Agro Ecological Zoning' of sugarcane to indicate the areas where sugarcane can sustainably be produced or expanded. The tendency in São Paulo state is that producing units are located in the west, displacing pasture and, to a smaller extend, other traditional crops (such as oranges). The government maintains a guaranteed minimum price for rice, beans, corn, wheat and cassava. There are sugar mills that can produce both sugar and ethanol, only sugar or only ethanol.

Costa Rica

The total production of sugarcane in 2010 was around 3.7 million tonne, which is for a small country like Costa Rica (5.1 Mha) the most produced commodity in the country (FAOSTAT 2012). No large-scale production systems exist due to geographical characteristics and active forest and biodiversity conservation policies. The average yield is 73.5 ton sugarcane/ha, and the average industrial yield is 6 to 10 litres of ethanol per tonne molasses. There are 2 factories in Costa Rica that are able to produce ethanol from sugarcane (out of in total 16 factories that process sugarcane), with a combined capacity of 55 Ml and actually producing 26 Ml ethanol which requires 40% of the nationally produced molasses. There is also one factory that can dehydrate imported ethanol and has a capacity of 110 Ml, actually producing approximately 99Ml. The protection of biodiversity hotspots is very important and the country is therefore quite proactively engaged in sustainability standards such as FSC (forestry), Rainforest Alliance (coffee), CST (tourism) and ISCC (sugarcane ethanol). Although economic indicators might be higher than neighbouring countries, the economy is fragile and dependents on foreign investments. Fiscal and trade deficits are growing. There is a lack of maintenance and new investments in infrastructure. The country is sensitive to inflation.

50% of the workforce in the sugarcane sector is required for harvesting. Activities are partly mechanised, one harvester replaces 250 field workers. Mainly seasonal employment. Workers are often contracted indirectly through an intermediary employer (this can dilute employer responsibility (Cerdas Vega 2007), wages are paid per ton or metre sugarcane harvested. In Costa Rica many workers on the sugarcane fields are from Nicaragua where wage levels are lower, indicating that working conditions are not attractive to the Costa Rican workforce. There is no trade union in the sugarcane sector and freedom of trade unionism is limited. However, multiple social benefits are provided to the permanent employees. Nearly 26% of the households are food insecure, mainly because of poverty issues. There is a high share of imports of major staple crops as well as crop inputs, and a specialization in crops for export such as coffee and pineapple. This makes the country very sensitive to exchange rate fluctuations, the share of income used on food increased rapidly when the national currency is losing value.

A general trend is an increasing share or large firms in main agricultural productions and a decreasing share of smallholders (rather people become employees). The administration and management of land is under the ministry of environment, energy and telecommunications. Costa Rica is not exploiting any fossil energy, and energy consumption has been increasing. There is a high dependency on import, so the country is vulnerable to oil price fluctuations. There is a trend to reduce hydropower capacities because of increasing water scarcity and quality, vulnerability to earthquakes, acceptability problems with new dams and poor legislation on hydrological resources. It is prohibited to generate geothermal energy in national parks and other protected areas. There are only a few women employed but this might be due to the harsh circumstances in the field. The number of women that have graduated as engineer is increasing. The low attractiveness of the producing province might skew the image (Cárdenas and Fallot 2011).

Canada

Canada has one of the largest forest estates in the world with about 397 million ha of forests, representing 10% of the world's forest cover and which has been fairly constant over the past decades(FAOSTAT 2012).Canada developed a National Forest Strategy in 1992, to commit to sustainable forest management. In 2006 the government announced a biofuel strategy to increase ethanol production, by requiring a 5% ethanol blend in gasoline for ground transport and 2% renewable content in diesel. The cellulosic bio-liquid industry is emerging, with little reliable data yet. No smallholder production systems exist, there are only large scale estates. The capital to labour ratio is higher than in the other countries. Canada is exporting electricity, mainly produced by hydropower. A major portion of the forests are held by federal and provincial governments on behalf of the monarchy, known as Crown Lands. Almost all of Canada is subject to Aboriginal title, to which Native groups can turn to solve land claim issues. Contemporary treaty and land claims negotiations are an attempt to resolve the question of Indigenous land rights. Canada has large oil and natural gas reserves. Gender inequality wage level is proven statistically, though difficult to quantify on company level. The enforcement of the national law is high compared to the other countries. Employment in the forest sector decreases.

7.6.2 Appendix B: case study results

There are two types of indicators; background indicators that give a more general idea of the country, not necessarily linked to biofuel developments, and indicators that link specifically to the biofuel sector. The results for both types of indicators are presented.

The country's abbreviations that are used are: Argentina (ARG), Brazil (BRA), Canada (CAN), Costa Rica (CRI), Indonesia (IDN), Mali (MLI), Tanzania (TZA) and Mozambique (MOZ).

1 Economic indicator results

Due to the size of the tables, the national (A), regional (B) and local (C) indicators are separated.

Table 7B-12: National level economic indicator results per case study

#	Indicator decription Q: Quantitative O: Other	Indicator result*	Measurement method / source
1A	**National level economic**		
	Background indicators		
	GDP	IDN: 371 billion € (2008) CRI: 35 billion $ (2010) or 25 billion € MLI: 8.7 billion $ (2009) BRA: 1,210 billion € (2010) CAN: 1,215 trillion € (2010)	(World Bank 2011) (CINDE 2009; BCCR 2011) CIA World Factbook data 2011 (World Bank 2011) Statistics Canada, 2010
	GDP per capita	ARG: 10,941 in current $ (2011) BRA: 12,594 CAN: 50,345 CRI: 8,676 IDN: 3,495 MLI: 669 TZA: 529 MOZ: 535	(World Bank 2011) (all idem)
	GINI coefficient [as %]	IDN: 38 in 2007 CRI: 49.8 (based on 2003), and 43.7 in 2009 TZA: 34.6 (2009) MLI: 40.1 BRA: 53.8 (2009) CAN: 32.1 (2005) ARG: 44.2 (2010)	(World Bank 2011) 2007/2008 UNDP, estado de la nation (World Bank 2011) (IPEA 2011) CIA, World Factbook data 2010 (INDEC 2011)
	People below the international poverty line of 1.25 $ a day (PPP) and below the national poverty line	IDN: 32% in 2006 (above national poverty line) ARG: 0.9 PPP (data from 2000-2009), 11% below national poverty line (in 2011) (57% in 2002) BRA: 2.8%, 21.4% (26% in 2008 case study rep) CAN: - (10.8% has income below 16,000 € CRI: 0.7%, 21.7% (1.25 $/day and national) IDN: 18.7%, 13.3% MLI: 51.5%, 47.4%	(World Bank 2006) (UNDP 2011) (UNDP 2011) CIA 2010, Statistics Canada (UNDP 2011) (UNDP 2011) (UNDP 2011)

		TZA: 67.9%, 33.4% MOZ: 60.0%, 54.7%	(UNDP 2011) (UNDP 2011)
	Human Development Index (HDI)	CAN: 0.888, 0.908 (2010 and 2011) ARG: 0.775, 0.797 CRI: 0.725, 0.744 BRA: 0.699, 0.718 IDN: 0.600, 0.617 TZA: 0.398, 0.466 MLI: 0.309, 0.359 MOZ: 0.284, 0.322	(UNDP 2010), (UNDP 2011)
	Indicators specific for bioenergy sector		
a.1	Sector contribution to GDP	IDN: export of palm oil accounts for 10% of foreign currency receipt BRA: 2% sugarcane sector contribution to GDP BRA: 2-10 billion $ increase depending on scenario ARG: 4% contribution of the soy chain CAN: 1.9% in 2008 , 1.7% in 2009 CRI: 1.1% (sugarcane to GDP)	GDP data from BPS, (Fischer 2010) data from sugarcane industry union (2008) Input/Output analysis GDP data from INDEC Literature (LAICA 2011)
a.2	Sector contribution to agricultural GDP	CRI: 14.4%	(Gómez 2008; LAICA 2011)
a.3	Estimated value of the sector	BRA: revenue from sugarcane: 4,562.7 million € for the mills and 3,658.4 million € for independent producers. From Ethanol: 8.85 billion €. CAN: Turnover of the forestry sector: P: $3,571 billion	Data from the sugarcane industry union Literature(Sleen et al. 2011)
a.4	Total investments in the sector	CAN: $20.0 billion in 2009	(Sleen et al. 2011)
a.5	Total taxes or royalties paid to the government by the sector	ARG: FOB price soy 838, soy export tax collection represents 30% of total export tax collection	
a.6	Products exported (quantity or value)	IDN: 8.2 million tons exported during first half of 2011. 42 million litres in 2006 (USDA, FAS, 2010) and 200 million litres in 2009 (USDA, FAS, 2010) ARG: 1.19 million tons soy biodiesel exported thru September 2011. 1200 million USD in 2010 CAN: value of export forestry is €30.2 billion	Data from GAPKI (6 monthly) indicates quantity and composition of exports, but not value. Ministry of Trade data indicates value but not disaggregated Data from INDEC (monthly with a lag of one trimester), USDA Database
a.7	Number of $ invested in bioenergy infrastructure over the past	CRI: no information	

	decade		
a.8	Value of industrial inputs	BRA: growth per sector e.g. 2.5 million euro industrial equipment in 2008	
a.9	Volume of bioenergy production by large plantations and smallholders	TZA: no data	(Sawe et al. 2011)

Note: The country's abbreviations that are used are: Argentina (ARG), Brazil (BRA), Canada (CAN), Costa Rica (CRI), Indonesia (IDN), Mali (MLI), Tanzania (TZA) and Mozambique (MOZ).

Table 7B-13: Indicator results per case study (regional economics)

#	Indicator description	Indicator result	Source
	Background		
	GDRP	ARG:0.8 million € (Santiago del Estero), 15 million € (Sante Fe) IND: North Sumatra: 22.7 billion € CAN: approx.. 120 billion € TZA: 607,098 million Tsh (2007) 946,309 million Tsh in 2007	(BPS SUMUT 2011) (BC Stats) 2010 (Sawe et al. 2011)
	Per capita income of the region compared to total per capita income	TZA: Arusha region 499 USD (2010) and 439 USD for mainland BRA: NE 3,400 € in 2008 (national is 12,600 $ in 2011) CAN: 22,700 €in 2009	(Sawe et al. 2011) (World Bank 2011) (BC Stats) 2010
	Regional GINI index compared to national GINI index	BRA: NE 0.556 in 2008 (IPEA), and national: 0.538 (2009) (IPEA)	
	Specific indicators		
b.1	% of bioenergy contribution to GRDP	BRA: 0.76% of NE economy BRA: 10-57% increase depending on scenario CAN: forestry accounts for 15% to province's economy	Calculation using added values Input/output analysis (BC Stats)
b.3	Regional turnover of sector	CAN:P: $4.4 billion (forestry) C: $11.4 billion	Literature (Sleen et al. 2011)
b.3	Regional sector turnover as part of total turnover	CAN: P: 15%	Literature (Sleen et al. 2011)
b.4	Regional investments in sector	CAN: P: $62.1 million (forestry) C: $1.9 billion	Literature (Sleen et al. 2011)
b.6	Quantity of bioenergy products exported from the region/% contribution of bioenergy product export to total exports	IND: NS: 4.3 million tons exported in 2009; approx 42% of NS exports Argentina: the soy core area accounts for more than 80% of the soy biodiesel exports.	BPS data (from Ministry of Trade) Exports data from INDEC and Ministry of Agriculture.

Table 7B-14: Indicator results per case study (micro economic indicators)

	Indicator description	Indicator result	Source
C	**Microeconomics**		
c.11	Contribution of bioenergy sales to household income (% or absolute value)	Indonesia: **AR:** NA **AR(P)**: €2,385 (Rp.28,968,000) per ha per year **AJ**: €1,622 (Rp. 19,691,000) per ha per year **HM**: €870 (Rp.10,560,000) per ha per year MLI: 15% increase in revenue by jatropha farming households in five years	Smallholder records and interviews
c.12	Costs of feedstock production	Breakdown of yearly production costs of the facility IND: AR: Data incomplete AR(P): €662 per ha current annual costs (45€/ha), AJ: €561 per ha current annual costs HM: €347 per ha current annual costs ARG: Viluco Plant: Planting Material 36,20 euro/ha ; Pesticides 61 euro/ha; Tools for harvesting 46,30 euro/ha; Storage 8,55 euro/ha; Transport 26,14 euro/ha CRI: 8304.79 €/ha CRI: 0.27 €/litre	Company records and interviews Company records and interviews; Margenes Agropecuarios statistics
c.13	Costs of feedstock conversion (Q)	IND: ARM: €16,384,624.23 (Rp 198,971,230,547) per year ARG: Plant XX : Electricity: 6 euro/ton of soy biodiesel; Feedstock: 198,93 euro/ton ; Labor 23 euro/ton ; Citric acid: 1,61/ton; Methanol 7 euro/ton (≈230 euro/ton). CRI: E 0.07 /l	Company records and interviews
c.14	Project investments	IND: 23 million € typically for 60,000 t/year refinery BRA:US$ 6 million for São Francisco Mill CRI: 20 M$ per distillery Canada: Pyrolysis: 21.1 million euro; Pyrolysis: 687€/kW MOZ: 2, 5, 12 and 4.8 M$ at 4 companies	(Ministry of Agriculture 2006) Interviews Interviews
c.15	Labour costs	CAN: Production: €42,593 Administrative: €57,442 BRA NE region Pindorama mill: 7.62% of the total costs are labour costs	Literature / interviews (Sleen et al. 2011)
c.16	Feedstock price	CAN: $50-$70 a tonne wood TZA: between 0.08-0.16 USD/kg jatropha seeds	Literature / interviews
c.17	Product selling prices	CAN: Ethanol: 553 euro / ton, Lignin: 222-422 euro /ton, Pyrolysis oil: 23 euro / ton MLI: jatropha biodiesel sold at 520 CFA/l (0.79 €/l). Jatropha seeds sold for 50 CFA (0.08 €/kg) possibly this will increase to 75 CFA (0.11 €/kg) IND: due to middlemen smallholders receive less TZA: depending on region from 0.09-0.19 $/kg seeds MOZ: intended selling price vs production costs; 850 USD/t oil vs 690 USD/t for one company (based on assumptions)	Literature / interviews (Sleen et al. 2011) TZA: (Sawe et al. 2011)
c.18	NPV	IND: average in Sumatra and West Kalimantan is 2,381 €/year and 1,862 €/year in more remote regions MOZ: 15.9 M$ (sun Biofuel)	(IFCA 2008) Interview
c.19	IRR (internal rate of return)	CAN: 25% MOZ: 50%, 27%, 7% for 3 companies	Interviews Interviews
c.20	PBP	MOZ: 8, 7, 4 (same companies as above)	Interviews
c.21	Turnover of the company/revenue generated	BRA: Pindorama mill in NE: R$ 125 million in 2009 MOZ: 18,000 USD in 2011 (Sun Biofuel) TZA: 2,560 kg seeds collected by women group in 2009 (*0.08-0.29 USD/kg)	Interviews Interviews (Sawe et al. 2011)
c.22	Revenue per ha from the	Mali: 110-340 €/ha for jatropha and 110-150 €/ha for rice production	literature and/or interviews

	bioenergy crop compared to revenues of other crops		
c.23	Competitiveness of the biofuel compared with the fossil alternative	MOZ: local price fossil diesel vs intended selling price jatropha oil (Mtc/l): 38 - 19 (Aviam), 41 - 35 (ADPP), 35-26 (Niquel), 38-36 (Sun Biofuel)	Interview and observations

The country's abbreviations that are used are: Argentina (ARG), Brazil (BRA), Canada (CAN), Costa Rica (CRI), Indonesia (IDN), Mali (MLI), Tanzania (TZA) and Mozambique (MOZ).

2 Employment generation - social well being - local prosperity indicator results

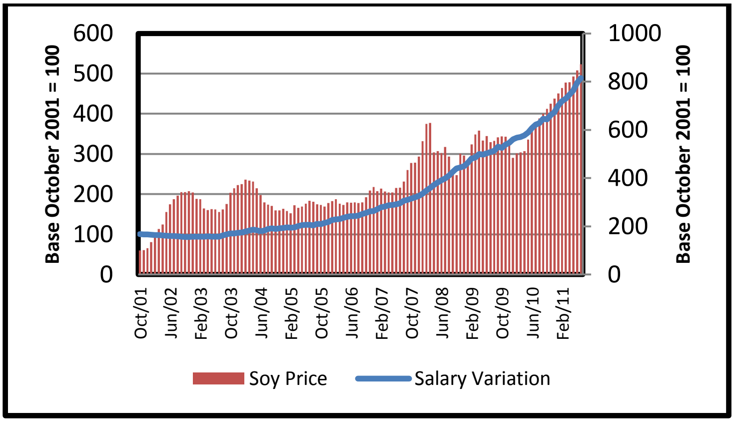


Figure 7B-4: Salary variation index and soy price (right axis) (based on CEDLAS data)

Table 7B-15: Employment generation - social wellbeing - local prosperity Indicator results per case study

#	Indicator description	Indicator result	Source
	Background indicators		
	Total labour force	BRA: total workforce in NE is 18 million people CRI: total labour force is 1.09 million IND: 116.9 million people (2010) North Sumatra: 6.3 million (2009) CAN: 18.4 million (2009) MOZ: 11.3 Million	 Statistics from (BPS) CIA World Factbook data 2010 Indexmundi 2011
	Unemployment ratio	ARG: 9.2 % in 2010 CRI: 7.8 % in 2009 IND: national 7.1 % in 2010, North Sumatra: 8.5% in 2009 CAN: British Columbia: 7.8% TZA: 11% (2.3 million people) in 2006 MOZ: unemployment Nampula 7%	Statistics Statistics Statistics from (BPS) (BC Stats) Integrated labour survey 2006

	Average (minimum) wage	IND: €2.11 per day , provincial minimum level: 79 €/month TZA: in Leguruki 1.36 $/day, although actually paid labour receives 0.68-1.36 $/day Official minimum wage: 80,000 Tsh/month MOZ: 2005 Mtc/month in agriculture	Statistics from (BPS)
	Total electricity generated	CRI: 9,504 TWh in 2009 MLI: 83 (ktoe) in 2007 CAN: 651,324 GWh in 2010 TZA: 4,185 GWh in 2007 ARG: 80 kTOE in 2008 (primary)	(Orozco et al. 2009) (DNE 2007) (Sleen et al. 2011) (Sawe et al. 2011)
	Total energy consumption	MLI: 2,249 ktoe (2007) TZA: 0.602 EJ in 2002	(DNE 2007)
	% of biomass in energy mix (primary energy supply covered by renewables)	CRI: 0.7 % (electricity only) MLI: 78% consumption CAN: 1.2% (from solid biomass) BRA: 31% (biomass in domestic energy supply) and 15.3% renewables	(DNE 2007) (Sleen et al. 2011) (BEN 2010)
	% of population lacking electricity access by grid	CRI: <1% TZA: 86% (and only 2.5% of rural population has access) In Leguruki: 100% IND: national: 8.5%, regional (NS) 7.4%	(BPS)
	% or value of petroleum products imported	MLI: 100%, 647 ktoe (2007) BRA: 0 % CAN: 0% TZA: 1.5 billion US$ in 2009	(DNE 2007) (Walter 2009) (Sleen et al. 2011)
	Firewood and charcoal demand	TZA: in Arusha region; 3,707 ktonnes of wood	(Sawe et al. 2011)
	General education level	BRA: 60% of the population in the NE have studied less than 9 years, 90% has 12 years.	
	Specific sector indicators		
2.1	Employment generation on national level	IND: 1.7-3 million jobs ARG: more than 1 million jobs from 1996-2006 in soy sector BRA:612,000 jobs in 2010 in the sugarcane sector of which 183,700 in the fields and 11,300 in the ethanol industry CAN: 273,700 jobs (exports) in 2008 CAN: 238,200 jobs in 2008	(Wakker 2004) (E.J.Trigo and Cap 2006) RAIS Statistics (Poon. J. (ed) 2004)State of Canada Forest report(Sleen et al. 2011)
2.1	Employment generation on regional level	IND: no accurate data available CAN: 7% are employed in forest sector TZA: estimated x smallholder farms BRA: NE region total number of employees in the sector 215,000, incl informal: 311,000	(Sleen et al. 2011)TZ: (PNAD 2010; RAIS 2010)
		BRA: increased employment in Northeast region of 10-57%	(Herreras Martínez et al. 2013b)
2.1	Employment generation on local level	IND: AR pl: 10 management and 377 field level jobs. AK mill: 72 jobs (8 management, 15 skilled and 49 unskilled) ARG: Plant x: 71 workers (full and semi-skilled), Viluco plant conversion: 284 Ca: X direct jobs, y indirect jobs; z temporary jobs TZA: x jobs in factory CRI: 1,210 persons during harvest, incl 300 workers from Nicaragua. Rest of the year employment is 490 people. 6 people per distillery MLI: 30 jobs at Mali Biocarburant (field agents) BRA: 4,000 workers during harvest season in São Fransisco mill, 1,823 for Pindorama mill (250 workers in the mill). MOZ: 205, 12, 280, 80, 45 and 170 (Aviam, adpp, niquel, sun bio, mocamgalp and Sab) total 792 jobs	IND: company records and interviews ARG: company records and interviews CAN: literature/interviews MOZ: interviews
2.2	Employment generation/ha	CRI: 1376 hours/ha (of which harvesting is 700 hours/ha) MOZ: 1.03, 0.19, 0.03, 0.27 and 0.71 for Aviam, niquel,	

		sun bio, mocamgalp and Sab	
2.2	Employment generation for conversion /ton biofuel	ARG: 71 workers for 250,000 tons/year makes 0.0003 workers/ton soybiodiesel	Company records and interviews
2.3	Percentage of informal jobs, total jobs generated included informal	BRA: 25%, total employment in 2010 including informal jobs is 837,000 (compared to 629,000)	(PNAD 2010; RAIS 2010)
2.4	Ratio of permanent contract vs temporary contract:	IND: Plant x: all casual labour TZA: x jobs family labour, x days/year CRI: 0.68 BRA: 50% (Pindorama) MOZ:55:150 or 0.4 (Aviam), 12:0 (ADPP), 230:50 or 4.6 (Niquel), 80:0 (SunBio), 12:33 or 0.4 (Mocamgalp), 120:50 or 2.4 (SAB), total 509 permanent and 283 temporary	IND: company records and interview MOZ: interview and company records
2.5	Ratio skilled versus unskilled jobs	IND: 8 management positions, 15 skilled and 49 unskilled jobs) ARG: 2 unskilled; 38 semi-skilled and 31 skilled CAN: 11 jobs community college level; 5 jobs university level MLI: x farmers, x seasonal workers, x skilled workers MOZ: 1:204 or 0 (AVIAM), 12:0 (ADPP) or 1, 10:270 or 0.04(Niquel), 11:69 or 0.2 (Sun Bio), 12:33 or 0.4 (Mocamgalp), 80:90 or 0.9 (Sab)	IND: company records and interview ARG: company records and interview CAN: interviews(Sleen et al. 2011) MLI: company info. MOZ: interviews and company documents
2.6	Ratio between local and migrant workers	ARG: 85% of employees are from local area. BRA: 20% of workers are temporary migrant workers during the harvest period	(Vuohelainen and Diaz-Chavez 2012)
2.7	Wage levels (including casual workers)	IND: AK pl management level 661 €/month and 35€ in benefits. Implementation level 91 €/month and 52€ in benefits. AK mill: unskilled workers 247 €/month plus 83 € in benefits. Agricultural wage labour in Harapan Makmur: 2.88 €/day ARG: Plant X: Unskilled labor 6.66 euro/hour Semi-skilled labor 10.38 euro/hour; Skilled labor 11.25 euro/hour, AG Bioenergy: unskilled (25 €/hour), semi-skilled (41,5 €/hour), skilled (46,5 €/hour). TZA: x Tshs, which is above minimum wage CRI: see table in (Cárdenas and Fallot 2011) BRA: Pindorama: basic salary of 242 €/month this is higher is productivity is higher. São Fransisco mill: a profit sharing programme for employees based on productivity incentive.	IND: company records and interview ARG: company records and interview CAN: literature BRA: Statistics TZA: interviews
2.8	Average wage in the company	ARG: conversion plant XX 2514 €/month[b], feedstock production plan AG Bioenergy: 44 €/day, conversion plant 88 €/day[c] or 2666 €/month MOZ:2005, 4000, 2300, 2500, 2005 and 2626 Mtc/month for Aviam, ADPP, Niwuel, Sun bio, Mocamgalp and Sab	Company documents and interviews MOZ: Company documents and interviews
2.9	Salary variation compared to crop price development	ARG: from 2001-2011 soy prices increase is followed by salary increase	Data from CEDLAS
2.10	Total wages and salaries in the sector	CAN: around 550 million € in 2008 (forestry sector in British Columbia)	(Sleen et al. 2011)
2.11	Income earned by smallholders	CRI: 16 €/tonne sugarcane IND: AK pl 25 €/month or rather 144 €/year, DAJ: 177 € /year HM: 43.60 €/month from selling FFBs (after costs have been deducted) TZA: 2,560 kg sold in 2009 by women group (is price is	Interviews and literature

		0.10 $/kg, they earned 256 $	
2.12	Share of income for large companies and smallholders	Tanzania; no data	
2.13	Job growth rate	CAN: decrease of 3.9-9.9% MLI: x new jobs by jatropha project y	CAN: forest sector in general MLI: company info
2.14	Average age	BRA: 35.4 years old BRA NE region: average age is 40 years, average age of working force 37, in sugarcane sector NE average is 34.6 yr	BRA: RAIS Statistics
2.15	Participation of different races	BRA: no data	
2.16	Wages at farm/company compared to wages in traditional activities (like charcoal making, food production)	TZA: opportunity costs of being employed less than forgone opportunity of charcoal production and some other activities BRA: NE region mean income is 153 €/month 2009, in sugarcane sector 245 €/month. National figures: average income for sugarcane employee is 237 €/month	TZA: analysis (PNAD 2010)
2.17	Wage levels sufficient to buy food and other household needs?	TZA: not possible to meet all household needs	TZA: analysis
2.18	Person days used in the biofuel activities by family labour at local level.	TZA: Threshold: Sufficient time left to grow own food (in case wages too low to buy all food)	
2.19	Regional employment in bioenergy sector as % of regional unemployment	MOZ: unemployment Nampula 7%	Statistic
2.20	Population that has increased energy access through bioenergy	TZA: 25 households and 17 business points connected through energy service platform (not exclusively on jatropha), 200 people benefit	Observation at the case study company
2.21	Education level of the employees	BRA: sugarcane sector employees have on average 5.7 years of education, in NE this is 3.7	Literature
2.22	Education by company	IND: smallholders in Harapan Makmur lacked access to information and therefore used poor planting material	Observation at the case study company
2.23	Community investment	ARG: community investment through foundation with annual budget of >725,000 € in 2011. BRA: € 1200 (2010), € 3200 (2011) plus contributions in-kind	(Vuohelainen and Diaz-Chavez 2012)

[a]: Indonesia abbreviations: AK pl=Aek Raso plantation, AKM: Aek Raso mill, DAJ: Desa Asam Jawa, HM: Harapan Makmur

[b]: Total labour consists of: 2 unskilled (1600€/month), 38 semi-skilled (2492 €/month) and 31 skilled workers (2700 €/month)

[c]: Total labour consists of: 43 unskilled (50 €/hour), 119 semi-skilled (83.3 €/hour), 122 skilled (93.3 €/hour).

Although in Brazil it was identified that a workforce in a company consisting of different races was important, it was not possible to find data on this (possibly due to potential discrimination if races are noted down).

3 Working and labour conditions indicator results

Table 7B-16: Working conditions Indicator results per case study(see also indicators on 2. Employment - local prosperity)

#	Indicator description	Indicator result	Source
3.1	Income spent on basic needs	ARG Viluco: information through survey applied to workers but not possible to correlate statistically (Vuohelainen and Diaz-Chavez 2012). BRA: similar to above	
3.2	Occurrence of forced labour	MOZ: does not occur at all 6 companies	Interviews with management and workers
3.3	Maximal number of hours of work per day or week	IND: the smallholders typically work 7-8 hours a day in DAJ and 6 in HM. 8 hours/day in the mill CRI: 8 hours/day (9 hours is legal max) TZA: 9 hours/day (8 hours is legal max) BRA: average in NE is 42 hours/week, in sugarcane sector in NE is 46 hours/week. In Pindorama mill: 8 hours/day (3 shifts), São Paulo mill 44 hours/week, 8 hours/day (3 shifts) MOZ: varying between 5-9 hours/day and 5-6 days/week see[a]	Interviews CRI: contract and interviews MOZ: Interviews with management and employees
3.4	Right to collective bargaining / respecting trade unions	IND: AR pl: workers are reported part of trade union, and company does not impede workers' freedom of association ARG: workers reported part of trade unions who are involved in collective salary negotiations CRI: no, firm's employee association CAN: possible internal and on sector level TZA: workers had no opportunity to establish workers union CRI: limited, employer controlled solidarity association MOZ: all except one see[b]	Company records and interviews MOZ: Interviews with management and employees
3.5	Extent to which child labour laws / minimum age are complied with.	IND: family farms / company reports no children are employed. But over 1.5 million children between 10-17 are working in the agricultural sector MOZ: minimum age is respected, see[c]	Company records and interviews (BPS-ILO 2009) Interviews with management and workers
3.6	Number of work related accidents	IND: regional level: 426 accidents, on 5 estates 47 accidents (2 deaths, 11 incidences of blinding by latex and resin and 32 light injuries). However, no data from companies. CRI:Minor burnings and crushed fingers were reported in Costa Rica. BRA: Pindorama mill: 15 accidents (resulting leave of absence 11 in field and 3 in mill) MOZ, records kept, see[d]	(Dep. NAKERTRANS 2011) and 2009 Interviews with management
3.7	Level of provision of Operational Safety and health systems, training and protective equipment	IND: AR pl: protective equipment provided. Smallholders: no use of protective equip. Ind: non provided / training provided TZA: protective equipment a, b, c, provided, needed equipment d, e and f not CRI: good for permanent employees enhanced with ISCC	Company records and interviews with management and workers

		certification process MOZ: always provided, see[e]	
3.8	Extent to which legal requirements for social security and accident insurance are complied with	IND: reporting that all legal requirements are complied with ARG: all legal requirements complied with[f] CRI: Yes, ok	Company records and interviews
3.9	Number of unjustified dismissals / end of contracts / resignations	BRA: 271,485 unjustified dismissals, 165,412 end of employment contracts, 83,212 resignations and 612,549 active employees	BRA: RAIS Statistics 2010
3.10	Duration of breaks	BRA: Pindorama: one hour lunch break MOZ: breaks: 30 min lunch break, (Aviam, ADPP), 30 min breakfast break and 1 hour lunch break (Niquel), 1 hour lunch break (Sun Biofuel), 20 min lunch break (Mocamgalp), 30 min lunch break (SAB).	Interviews
3.11	Mode of transport to the fields	CRI: Bus BRA: Pindorama: special busses	Company records and interviews
3.12	Right of training/education	CAN: company policy of 40 hours training per year for each employee BRA: Pindorama: professional training provided, educational projects are provided such as reading and computer classes, sewing, hand-craft and silk screen printing classes.	Company records and interviews (CAN: (Sleen et al. 2011))
3.13	Possibilities of retirement pension	ARG: in 2003 56% and in 2010 65% of the workers have access or right to pension	INDEC database
3.14	Change in access to health insurance	ARG: in 2003 56% and in 2010 65% of the working class has access to health insurance	CEDLAS database
3.15	Rights of casual workers (social security, medical assistance) compared to fully employed workers	TZA: casual workers have no overhead costs, social security and medical assistance.	Interviews
3.16	Right to understand the employment contract	TZA: cases in which contracts are in English while worker does not write/speak it.	Interviews
3.17	Other benefits	BRA: Pindorama: employees are provided with fresh water, bathroom facilities, shadow, tables and chairs and two snacks during working hours.: Pindorama mill: life insurance for all workers (incl. temporary). São Fransisco Mill: ambulance support for rural people in the field for first aid treatment and transport to health facilities, two ambulances are owned. MOZ: see [g] CRI: Installation of mobile bathrooms in the field and the provision of security equipment to workers were two improvements that were necessary for the case study company to obtain ISCC certification.	

[a]: Working hours: Aviam: 8 hours/day, 6 days/week, ADPP: 8 hours/day, 5.5 days/week, but the hours are flexible for extension workers. Niquel: 9 hours/day, 5 days/week. Sun Biofuels: 8 hours/day and 5-6 days per week. Mocamgalp: 5 hours/day, 6 days/week. SAB: 8 hours/day, 6 days/week.

[b]: UNIONS: Aviam: workers unions allowed and exist. Discussion points: working hours, lunch time and weekend. ADPP: monthly meetings. Niquel: Around 60% of the workers belong to the union and they talk to the human resources manager about possible issues. Sunbiofuels: There is a syndicate representing the workers, which discusses with management about salary, clothing and equipment. Mocamgalp: No unions, according to a managing technician, who states that this is not necessary, because everything is okay, Sab: the union discusses with management about salary and working hours. Also, SAB works together with the local governmental work inspectors.

[c]:The minimum age to work at Aviam: 18 years, ADPP: 22 years, Niqel: 22 years, Sun Biofuels: 18 years, ASB: There is no official minimum age to work at SAB, but they never hire below 20 years old, MoçamGALP: 25 yrs.

[d]:Work related accidents: Aviam: they are monitored, one minor injury occurred. ADPP: Work related accidents are not tracked, because no real accidents have happened, only some minor injuries such as cuts and bruises. Niquel: Records of accidents are kept. Over the last 4 years, there has been one serious injury with a broken arm. This was reported to the insurance and government. Sunbiofuels: Records of accidents are kept. There have been a few accidents, with one big accident where a lorry toppled over and several people past away. Insurance covers all work related accidents. SAB: Records of accidents are kept. The only situation that occurred was that the chief agronomist was declared unable to work, because of unknown reasons.

[e]: Protective equipment: Aviam: When working with chemicals, protective equipment is used, such as an overall, boots, mask and gloves. However, sometimes workers do not have access to all this protective equipment. ADPP: When working with chemicals in the factory, protective masks are used. Outside the factory no chemicals are used, only organic materials. Niquel: When working with chemicals, workers use overall, masks, glasses, hats and boots. Sunbiofuels: When working with chemicals, workers use overall, masks, gloves and boots and fresh milk afterwards. Mocamgalp: When working with chemicals, workers use masks, gloves and boots and fresh milk afterwards. SAB: When working with chemicals, workers use overall, masks, glasses and fresh milk afterwards

[f]: laws that apply in Argentina: Employment Contract Law no 20,744, No 11,544 (working hours) No 24,557 (occupational accidents and professional diseases), Nos 24,013 and 25,323 (labour indemnities, labour fraud). Law No 14,250 (1953) and its amendments regulates union agreements. Law No 24,557 (Occupational Risk Law)

g: AVIAM has the plans to build a new hospital/maternity center, but there has been no progress yet. The same goes for a new school and a football field. These have been promised according to the community leader, but nothing has happened yet and the community leader doubts whether this will still happen. The total investments of these contributions cannot be retrieved, since the plans have not been executed. ADPP helped build a bathroom in a local school. Also, ADPP educates teachers, who can teach at local schools. ADPP works with outgrowers and the extension workers that work for ADPP train the outgrowers how to cultivate Jatropha and also how to cultivate food crops. ADPP also said to provide the outgrowers with supplies needed for the cultivation of Jatropha, but this has not been followed up on in every case (management and community interviews). Niqel constructed over 70km of roads and bridges. Niqel states they also have plans to build a school, a police station, a medical clinic and new houses. The community confirms this, but also says none of these plans have been executed yet. However, renovations on a hospital have been done and also a football team was created. Sun Biofuels restored a police station, fixed a medical clinic and built a community office. Also, they provide water through piping and a school was built. Furthermore a church was promised, but that did not go through. MoçamGALP purchased 20 computers for a local school. SAB built a hospital and a water pump to provide the community with water. Furthermore, SAB sprayed the village against mosquitoes and they created a football team. SAB also said to build a school, but it unsure whether this will go through.

4 Health and safety indicator results

Table 7B-17: Health indicator results per case study

#	Indicator description	Indicator result	Source
	Background indicators		
-	Average number of people per health facility (national, regional, local)	IND: national: 27,406 North Sumatra: 26,443 District Labuhan Batu: 38,000	(BPS) (BPS)
-	Average number of people per doctor	IND: national 0.3 per 1000 people North Sumatra: 0.22 per 1000 p District Labuhan Batu: 0.16	(BPS SUMUT 2011)
4.1	Number of workers reporting health concerns related to agrochemical use	IND: no data provided / no data available ARG: no cases reported CRI: direct causality not established, Costa Rica with high cancer rates	IND: company/health clinic records and interviews
4.2	Level of compliance with a given standard for waste treatment and disposal	IND: no data provided / no data available ARG: full compliance CRI: internal use of vinasse, limited access to data	IND: company records ARG: company records
4.3	Number of accidents during work, as proportional to the total number of workers	CAN: 6 medical aid (off-site), 8 lost time accident, 1 fatality in 2010 (employees+contractors) BRA: Pindorama: 15 accidents (11 in field and 4 in mill) in 2009/10. São Fransisco: in 2009 3,392 attendances to emergency assistance were made.	Sustainability report 2010(unpublished) BRA: Interviews CAN: (Sleen et al. 2011)
4.4	Number of deaths during work, as proportional to the total number of workers	BRA: regional level: x death due to labour accident; x death due to traveling to workplace; x deaths due to labour related diseases.	BRA: regional level: RAIS statistics
4.5	Number of retirements due to working accidents, as proportional to the total number of workers	BRA: x retirement due to labour related diseases; x retirements due to labour accident.	BRA: regional level: RAIS statistics
4.6	Benefits for disability and fatalities	CAN: x Euro	CAN: literature
4.7	Health and safety policies	CAN: Company x has an Occupational health and safety policy IND: AR pl: free healthcare to employees and outgrowers in primary health care clinic. Common services: checkups, immunisations and pregnancy care.	CAN: interviews (Sleen et al. 2011)
4.8	Noise above legal threshold	CAN: can be achieved with the right countermeasures	CAN: interviews (Sleen et al 2011)
4.9	Risk of fire outbreak	CAN: Chance of dust explosion or fire in machines. Right countermeasures are taken.	CAN: interviews (Sleen et al. 2011)
4.10	Risk of gas emissions	CAN: Gas emissions are possible. Right countermeasures are taken	CAN: interviews (Sleen et al. 2011)
4.11	Number of staff with medical insurance	TZA: not measured	TZA: data to be collected on national level.
4.12	Investment in health facilities by bioenergy company	IND: AK pl: health clinics which is available for staff and smallholders, free of charge	
4.13	Change in access to health care	IND: smallholders DAJ reported no direct impact, none made use of the plantation health clinic services. Smallholders HM are not located close to plantation health clinics therefore no change in access ARG: 56% in 2003 and 65% in 2010 of working class had access to health insurance	CEDLAS database

		MOZ: see work&labour conditions	

The country's abbreviations that are used are: Argentina (ARG), Brazil (BRA), Canada (CAN), Costa Rica (CRI), Indonesia (IDN), Mali (MLI), Tanzania (TZA) and Mozambique (MOZ).

5 Food security indicator results

Table 7B-18: Food security indicator results per case study

#	Indicator description	Indicator result	Source
	Background indicators		
	Food security index	IND: regional: 4-6 Tanzania: Leguruki village scores 2.49	
	Population that is food insecure [%]	CRI: 26% of the households BRA NE region: 53.5% of population has access to sufficient food	(Delgado et al. 2010) (IBGE 2006)
	Poverty rates	IND: NS: 11.51% in 2009 ARG: Last available data : 11% in 2010	(BPS) Statistics
	% of household income spent on food	IND: NS: average 63.2% of income spent on food AJ: est 20% of income spent on foodHM: no data	BPS data (down to district level). SEIA at local level
	Prevalence of undernourishment [%]	ARG: <5, BRA: 7, CRI:7, MLI: 8, TZA: 39, IDN: 9, CAN:-, MOZ: 39	(FAOSTAT 2012)
	Calories per capita	BRA: - CAN: 3,350 (kcal/caput/day) in 2009-2011	(FAO 2009)
	Staple crop production	MLI: Cereals are staple crop: rice (1.95 Mt), maize (1.48 Mt), sorghum (1.47 Mt) and millet (1.39 Mt). BRA NE region: sugarcane (1.4 billion €), banana (1.4 billion €), maize (786 million €) and cassava (636 million €) BRA NE region: sugarcane (59 Mt), cassava (8 Mt), maize (5.5 Mt) and soy (3 Mt)	FAOSTAT 2011 (IBGE 2010) (IBGE 2006)
	Main regional staple crop production	ARG: Soy 2.9 m ton, Maize 0.6, wheat 0.2 m ton Soy 10 m ton, maize 4 m ton, wheat 1.7 m ton	Santiago del Estero Santa Fe (INDEC 2010)
	Quantity and type of foodstuff missing in the local community	TZA: no data	
	Specific indicators		
5.1	Protection programmes	CAN: Tembec protects biodiversity and water bodies. BRA: Pindorama: vegetable garden and pepper garden where locals can grow products for own consumption	Interviews CAN: Sleen et al. 2011
5.2	Providing alternative for current practices	CAN: Conversion solves part of the problem, because ethanol is now produced from wood instead of agricultural products	Literature CAN: Sleen et al. 2011
5.3	Number of people that became food insecure due to bioenergy production	TZA: no data	
5.4	Previous land use of bioenergy crop area	IND: AR pl: previously state forest land, not in use for food production. DAJ: no impact on food crops due to palm cultivation HM: land previously used for rice production.	

5.5	Change in access to food due to bioenergy	IND: AK pl, improved income, therefore likely that food access increased. DAJ: income improved. HM: converted from rice to palm oil therefore loss of food access because income has not been generated yet (due to early years of palm establishment).	
5.6	Conversion rates of food producing land due to bioenergy	IND: HM: 975 ha of rice production was lost since 2005 Canada: Not the case in Canada /BC except for mushrooms, honey, berries etc. collected from forests	Ministry of Agrigulture data (nat/reg scales) SEIA or food security assessment (local scale) Literature
5.7	Perceived change in food security	MOZ 78% of respondents (21 people) said they perceived no change or an improvement	Interviews among 27 jatropha farmers
5.8	Δ in household income spent on food[%] before-after biofuel project	MOZ: from 50 to33% (Aviam), from 53 to 56% (ADPP), from 72 to 46% (Niquel), from 78 to 66% (Sun Bio), from 60 to 70% (SAB)	Interviews employees
5.9	Δ in average time spent on food production	MOZ: same (Aviam), from 23 to 4 h/wk (ADPP), from 25 to 9 h/wk (Niquel), from 24 to 14 h/wk (Sun bio), from 19 to 4 h/wk (Sab)	Interviews farmers

The country's abbreviations that are used are: Argentina (ARG), Brazil (BRA), Canada (CAN), Costa Rica (CRI), Indonesia (IDN), Mali (MLI), Tanzania (TZA) and Mozambique (MOZ).

6 Land rights indicator results

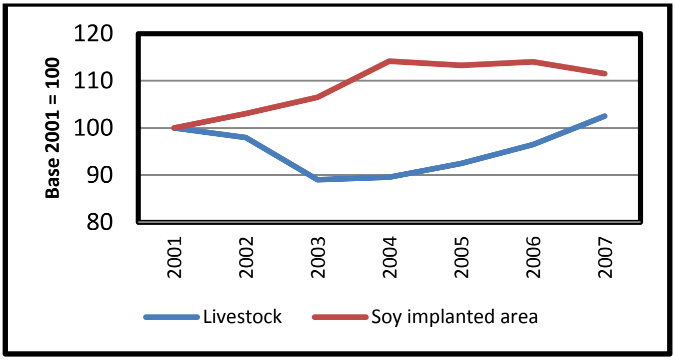


Figure 7B-5: livestock and areas with soy cultivation developments up to 2007 in Santa Fe

Table 7B-19: Land right related indicator results per case study

#	Indicator description	Indicator result	Source
6.1	The extent to which land acquisition followed the correct legal process	IND: AR: No data provided, AR(P): NA, AJ: NA, HM: NA ARG: Correct legal process was followed	Company records and community interviews. SEIA Company records

6.2	The extent to which community land rights are determined and mapped	IND: AR: No data provided, AR(P): NA, AJ: NA, HM: NA ARG: In the areas of this study no conflicts regarding land competition has been reported. Community land rights are complied. MOZ: 4 out of 6 companies assessed previous land rights	Company records and community interviews. SEIA Company records and INDEC
6.3	The extent to which the principles of FPIC are followed in dealings with local communities and indigenous peoples, including when handling disputes	IND: AR: No data provided, AR(P): NA, AJ: NA, HM: NA	Company records and community interviews. SEIA
6.4	Number of conflicts due to biofuels expansion	BRA: - IND: North Sumatra; social conflicts: 136 conflicts in 2008, related to palm oil: 13 MOZ: land conflicts after discontinuation of projects	(Sawit Watch 2008)
6.5	Expansion area over other crops/land uses	ARG: data available BRA: *65% pasture; 17% soy; 5% corn; 6% others; 2% frontiers TZA: no data	See 6.6
6.6	Coefficient of expansion area of the crop vs other sector (livestock)	ARG: -0.02 from 1980-1999 and 0.01 from 1980-2009	Via econometric model
6.7	Compensation payments	MOZ: 3000-11,000 Mtc (Aviam), furthermore other companies provided community development programs	Interviews
6.8	Language of contracts	CRI: no data MOZ: Portugese and Makua language (Aviam), Enligh and local language (Niquel), Portugese (Sun biofuel)	Interviews
6.9	Availability of documentation for local communities	MOZ: only available for 4 relocated families (Aviam)	Interviews
6.10	Lost rights to land	CRI: no data	
6.11	Coherent land ownership structure	CAN: Stable over the years in Canada/BC little more to Aborginal jurisdication	(Sleen et al. 2011)
6.12	Availability of treaties on land use issues with native local stakeholders	CAN: Tembec does have these treaties in place. They are for example working together with the first nations and have resolution mechanisms	Interviews (Sleen et al. 2011)
6.13	Hectares of land suitable for bioenergy production	TZA: no data	
6.14	Hectares under public land	TZA: data available by TIC (investment center)	
6.15	hectares under bioenergy cultivation	TZA: no updated data available ARG: almost 20 million ha in 2009	
6.16	Development of land prices	ARG: data available	National database
6.17	Area under bioenergy production as percentage of total planted area	ARG: 55.9% of the land is under soy cultivation	Statistics

The country's abbreviations that are used are: Argentina (ARG), Brazil (BRA), Canada (CAN), Costa Rica (CRI), Indonesia (IDN), Mali (MLI), Tanzania (TZA) and Mozambique (MOZ).

7 Gender indicator results

Table 7B-20: Gender related indicator results per case study

#	Indicator description	Indicator result	Source
	Background		
-	Gender-related Development Index (GDI)	IND: national: 90% of HDI, North Sumatra:87% in 2002	(UNDP 2004)
-	Gender Empowerment Measure (GEM)	IND: national: 0.546 in 2002 and North Sumatra: 48.4	(UNDP 2004)
-	Right of land ownership for women	TZA: women do not own land	TZA: literature
-	Benefits distribution between men and women in the family.	TZA: no equally distributed	TZA: interviews, literature
-	Female unemployment rate compared to average unemployment	IND: national: 9.7 % compared to 7.5% for men in 2008, North Sumatra: 10.5 while men 7%	(Dep. NAKERTRANS 2011)
-	Labour employment gap between men and women	CAN: x % in 2011	CAN: national statistics
-	Presence of organizations for women's rights	CAN: several organisations on national level	CAN: internet
7.1	Women's wages as a % of men's (doing work judged objectively to be similar)	IND: nationally women earn 76% of what men earn DAJ: women earn 2.22 €/day, men 4.12 €/day for unskilled labour HM: both earn 2.88 €/day nd: no data provided / available; interview results: women get paid less in plantations, as they do the "lighter work". "Housewives" work occasionally in the fields. ARG: no disparities between wages were reported however this type of activity is driven mainly by men workforce. women earn 98% of men's wages in general CAN: wage gap of x % TZA: in field women get paid equally	(World Bank 2011) Interviews interviews IND: n.a. / interviews CAN: national statistics TZA: interviews
7.2	The extent to which equal opportunities are extended to women and men in the workplace	IND: no or insufficient data provided ARG: no data available	n.a.
7.3	The extent to which women's reproductive rights are respected	IND: no data available; interview results: no women's participation in agrochemicals use (which can be bad for reproduction). ARG: Maternity leave is regulated by law TZA: maternity leave for women (sometimes unpaid)	IND: n.a. / interviews TZA: interviews
7.4	Participation of women (in a type of job, company or sector)	CRI: x % female participation CAN:11.3% women employees in 2010 BRA: 90% of employees in the sugarcane sector are men, in the NE region this is 95% IND: AR pl: 97% men, only 10 women they are in administrative job. No women in management. ARG: mill: 86% male employment, 4 women working in services (book keeping and waitressing). National data: in 1998 180,000 women were employed in agriculture, in 2002 only 120,000 MOZ: in one company 50 female workers out of 230	CRI: interviews CAN:Interviews ARG: INDEC
7.5	Women participation policies	CAN: Canada has a Human Rights Act and Multiculturalism Act	CAN: literature(Sleen et al. 2011)

		IND: no policy at AR plantation and mill	
7.6	Contribution of bioenergy project to gender equality	TZA: training programmes are sometimes specifically directed towards women groups (e.g. soap making)	TZA: interviews
7.7	Benefits created for women	BRA (Pilon): female workers have right to 120 days of maternity leave. Female workers do not work with pesticide application (Vuohelainen and Diaz-Chavez 2012). ARG (Pilon): legally: maternity leave, hour/day for breastfeeding (up to year), maternity bonus (€ 98)	ARG: (Vuohelainen and Diaz-Chavez 2012)

The country's abbreviations that are used are: Argentina (ARG), Brazil (BRA), Canada (CAN), Costa Rica (CRI), Indonesia (IDN), Mali (MLI), Tanzania (TZA) and Mozambique (MOZ).

8 Summary and conclusions

8.1 Research context

The global demand for energy, and associated services, is increasing. Fossil fuels dominate the current energy supply and this leads to a rapid growth in global greenhouse gas (GHG) emissions. There are multiple options for lowering GHG emissions; one of them is using renewable energy (IPCC 2012). There are various possibilities to generate renewable energy via solar, wind, geothermal or biomass resources. The advantage of biomass is that the production of biomass for energy generation can contribute not only to climate change mitigation and energy security, but also to rural development and employment generation, to postive impacts on (regional) GDP, and to mitigation of local pollutant emissions. Furthermore, bioenergy is versatile because it can be deployed as solid, liquid and gaseous fuels for a wide range of uses, including transportation, heating, electricity production, and cooking (Faaij and Domac 2006; Chum et al. 2011). The total technical bioenergy potential can go up to 500 EJ/yr in 2050 (Smeets et al. 2007).Many developing countries have a large potential for supplying bioenergy feedstocks (van der Hilst et al. 2011; Wicke et al. 2011; Batidzirai et al. 2012a).

Bioenergy feedstock production in developing countries can have many positive socio-economic impacts on different scales such as raising and diversifying farm income, increasing rural employment, general improvement of the local livelihood, supporting local services, and improvement in agricultural techniques and local food security, increased access to energy and an improvement of working conditions (Ewing and Msangi 2009; Wicke et al. 2009; Arndt et al. 2011; van der Horst and Vermeylen 2011; Walter et al. 2011; Diaz-Chavez et al. 2013). However, the production and use of bioenergy does not necessarily contribute to sustainable development. Negative impacts include environmental problems such as deforestation and loss of biodiversity, but also competition for arable land and related resources and consequent social impacts on food security, tenure arrangements, displacement of communities and economic activities, deforestation, impacts on, and unequal distribution of costs and benefits and economic unsustainability (Sala et al. 2000; Mitchell 2008b; World Bank 2010b; German et al. 2011a; Diaz-Chavez et al. 2013; IPCC 2014). The production and use of biofuels which includes various production systems, business models, conversion technologies, capital intensity, and transport, in short; bioenergy systems can thus cause both positive and negative effects and their deployment needs to be in balance with a range of environmental, social and economic objectives. Co-benefits and risks do not necessarily overlap, neither geographically nor socially (Dauvergne and Neville 2010; Wilkinson and Herrera 2010; van der Horst and Vermeylen 2011). This means that multiple sustainability issues across multiple spatial scales and across development and deployment time scales have to be addressed. Furthermore, a correspondingly diverse array of sustainability assessment criteria and methodologies are needed, in order to enable adequate bioenergy investment decision-making and monitoring of projects during implementation (van Dam et al. 2010b). Much is still unclear about the exact circumstances under which bioenergy cultivation and processing are likely to produce beneficial results, and under which circumstances they are likely to induce harms, and about the pivotal factors that drive these diverse outcomes in specific situations.

Due to the sheer growth in production and trade volumes, socio-economic and environmental sustainability issues surrounding production and processing of biofuels have been steadily growing in importance. One option to ensure the sustainable production and trade of biofuels is the application of certification systems and initiatives, for which there is globally an increased focus (van Dam et al. 2008a; Diaz-Chavez 2010; van Dam et al. 2010b; Vissers et al. 2011). Fully operational sustainability certification schemes and initiatives mainly focus on environmental principles, even though there are also serious concerns about socio-economic impacts of bioenergy production activities (van Dam et al. 2010b; German and Schoneveld 2012). The lack of studies that include empirically examined (positive or negative) social impacts at the local level is also acknowledged by Hodbod and Tomei (2013), and by van Dam et al. (2010b), who indicated that certification should be combined with additional impact measurements and methodological tools on a regional, national and international level. Another obstacle to ensure the sustainability of biofuels is that data requirements are often found to exceed the resources and capabilities for reliable data collection in many developing countries from which biofuels are sourced (van Dam et al. 2010b). Obtaining good quality field data is difficult due to cultural, infrastructural and other barriers. In addition, some certification schemes are designed primarily with western conditions in mind, which deviate substantially from conditions in the rural areas of many developing countries, e.g. with respect to farming systems, farm sizes, and land use and ownership laws (Romijn et al. 2013). The lack of reliable data is problematic because certification systems cannot function effectively and efficiently without them (van Dam et al. 2010b).

8.2 Aim and research questions

This thesis aimed to contribute to an improved analysis and measurement of socio-economic impacts of biofuels in developing countries. Under this overarching objective was subsumed an analysis of how these impacts relate to scale, type of biomass and bioenergy produced, the contextual setting and the identification of production systems with the most positive and least negative socio-economic sustainability impacts.

Therefore, the following research questions were addressed:

I. What are the most important determinants of the socio-economic impacts of bioenergy systems in developing countries?
II. What is the importance of different scales (local, regional, national, global) on these impacts?
III. What methodologies and tools can be developed to measure these socio-economic impacts?

The research questions were addressed in chapter 2 through 7. Each chapter evaluated socio-economic impacts of biofuels in different settings and geographical scales. Table 8-1 presents an overview of the chapters and the research questions addressed.

Table 8-1: Overview matrix of the thesis chapters and the research questions addressed in them.

Chapter	Research questions		
	I	II	III
2 The economic performance of Jatropha, cassava and Eucalyptus production systems for energy in an East African smallholder setting	✓	✓[a]	
3 Comparative analysis of key socio-economic and environmental impacts of smallholder and plantation based jatropha biofuel production systems in Tanzania	✓	✓[b]	✓
4 Current and future economic performance of first and second generation biofuels in developing countries	✓	✓[c]	
5 Global experience with jatropha cultivation for bioenergy: an assessment of socioeconomic and environmental aspects	✓	✓[d]	
6 Analysis of socio-economic impacts of sustainable sugarcane-ethanol production by means of inter-regional input-output analysis: demonstrated for Northeast Brazil		✓[e]	✓
7 Identification and analysis of socio economic indicators; illustrated by bioenergy systems in eight case study countries		✓[f]	✓

[a]: Regional and local scale, [b]: Local scale, [c]: Global and regional scale, [d]: Global and local scale, [e]: Regional scale, [f]: Global, regional and local scale

Chapter 2 analysed the economic performance of three bioenergy crops (Jatropha, Cassava and Eucalyptus) in a specific smallholder setting taking the opportunity costs of labour into account. The focus of this study was inspired by the large numbers of poor smallholders in developing countries who might benefit from growing bioenergy crops, combined with the lack of reliable data about the economic feasibility of such investments in a smallholder setting. Chapter 3 made a comparative impact analysis between a jatropha smallholder model and a large-scale plantation model, because these models are widely used, whereas the differences in impacts had not been analysed in detail so far. Chapter 4 analysed the economic performance of 8 feedstock types in 12 countries covering 74 different settings in total, to obtain more insight in the variables that influence the performance in specific settings. Chapter 5 analysed the actual impacts of jatropha projects worldwide on the local scale. Chapter 6 demonstrated a methodology to address socio-economic impacts on a regional scale by using an input-output analysis on sugarcane production in Northeast Brazil. Chapter 7 identified and evaluated socio-economic indicators on all three scales to be used in certification systems and to measure the impact of bioenergy projects using these indicators.

8.3 Summary of the findings

In this section, the chapters are summarized, followed by the main findings and answers to the research questions. The following countries and feedstocks have been assessed in this thesis, see Table 8-2 for an overview:

Table 8-2: Overview of countries and feedstocks assessed in this thesis*

	Soy	Sugarcane	Oil palm	Jatropha	Cassava	Energy grass	Short rotation (eucalyptus, poplar)	Residues (rice, wheat straw)
Africa								
Mali				✓				
Mozambique		✓			✓		✓	
Tanzania				✓	✓		✓	
Americas								
Canada							✓	
Argentina	✓					✓[b]		
Brazil		✓					✓	
Colombia			✓					
Costa Rica		✓						
Asia								
China								✓
India				✓				
Indonesia			✓					
Malaysia			✓					
Thailand					✓			
Europe								
Ukraine							✓	✓

*: In addition to the countries indicated in the above table, the impact of Jatropha projects has also been reviewed in: AFRICA: Cape Verde, Burkina Faso, Ghana, Ivory coast, Kenya, Malawi, Ethiopia, Zimbabwe, Swaziland, Namibia, Zambia; AMERICAS: Honduras, Guatemala, Mexico, Peru; ASIA: Cambodia, Myanmar.

Chapter 2 addressed research question I and II, and compared the economic performance of jatropha, cassava and eucalyptus cultivation by smallholders in East Africa. All family labour settings (representing a scenario of zero labour costs) yield positive Net Present Values (NPVs), and high Internal Rates of Return (IRRs) and Benefit Cost Ratios (BCRs). Cassava using family labour has the highest NPV (2900-5800 US$ ha^{-1}) and the shortest payback period (PBP), but the required investment costs are high in comparison with the other crops. If hired labour is used, the NPV of eucalyptus is highest (380-1400 US\$ ha^{-1}), and it is also the least sensitive to changes in wages and yields. Jatropha performs best only on the IRR indicator and only with family labour or low labour opportunity costs. The analysis and comparison of bioenergy production costs shows that eucalyptus pellets (2.6-3.1 US\$ GJ^{-1}) are competitive compared with reference pellets at current market prices (5 US\$ GJ^{-1}). Jatropha SVO (19 US\$ GJ^{-1}) and cassava ethanol (19-36 US\$ GJ^{-1}) are only competitive with fossil diesel (21 US\$ GJ^{-1}) and petrol (25 US\$ GJ^{-1}) in a family labour setting. At current values jatropha biodiesel (24-37 US\$ GJ^{-1}) is not competitive. The economic performance is sensitive to variations in crop yields and yield data are highly uncertain. This chapter demonstrates that there is considerable potential for increasing the economic performance by further improvements in yield, harvesting efficiency and conversion efficiency as well as reductions in transport and packaging costs.

The results of **Chapter 3** indicate that both the decentralized smallholder jatropha model and the centralized plantation model can lead to positive socio-economic and environmental impacts, but substantial differences are also apparent. The smallholder model scores better on land rights, GHG balance and biodiversity and it reaches more people, whereas the plantation model creates more employment and higher (local prosperity) benefits for smaller numbers of people, and could lead to higher yields. Negative impacts of the smallholder model (jatropha grown in hedges) are minimal, whereas the plantation model could lead to decreased food security, loss of land rights and biodiversity. This could permanently affect the livelihood situation of the local population, but this is not inevitable as there is considerable scope for implementing mitigating policies. The way in which a particular model is implemented in practice, its management and company values, can have a major influence on the actual impacts. However, the biggest hurdle towards achieving sustained positive societal impacts in both jatropha models is their marginal profitability at current yields, costs and oil prices. Still, these results are highly sensitive to uncertain yields and oil prices. Better outcomes in the future are expected. A reliable sustainability assessment was found to require many location-specific and operational company data.

Chapter 4 analysed the economic performance of first and second generation biofuels in 74 settings, covering 5 fuel output types, 8 feedstock types, 12 countries and 8 combinations of agricultural management systems between 2010 and 2030, by estimating their net present values and performing total production cost calculations. Yields are assumed to increase over time due to better crop management and improved varieties. High NPVs (meaning profitable production) are obtained for cassava (up to 16,000 US\$/ha) and palm production (up to almost 7,000 US\$/ha). But there are also scenarios in which cassava yields a negative NPV which indicates that the project investment comes with risks of unprofitable production. The NPVs for jatropha range from -900 to 2000 US$/ha, while for sugarcane and soy the NPVs are positive in all analysed scenarios (2500-5000 US$/ha and 200-3000 $/ha respectively), and therefore these crops are expected to constitute a profitable investment. Total biofuel production costs in 2010 are estimated to vary from 5-45 US$/GJ for 1st generation feedstocks in 2010, and from around 10-35 US$/GJ in 2020, compared to 20-30 US$/GJ for fossil fuels. Argentina and Malaysia are the regions with the lowest production costs for biofuel (soy and palm biodiesel for 8-10 US$/GJ and 8-23 US$/GJ respectively), although potential for cost reduction exists in other regions. Production costs of 2nd generation biofuels are estimated to be 17-26 US$/GJ in 2020 and 14-23 US$/GJ in 2030. Poplar based synfuel production in Ukraine has the lowest costs (14-17 US$/GJ) and rice straw based bioethanol the highest (23-26 US$/GJ) - for both the short and long term. The costs ranges (including uncertainty ranges) of 2nd generation feedstocks are high, but they are within similar cost ranges as for 1st generation feedstocks. The pay-back time on investment, as well as the size of investment and the alternative commodity markets, varies with the type of feedstock. The choice of suitable feedstock therefore depends on the local agricultural system, and the preferences and means of the local farmers. Key to the competitive production of 2nd generation fuels is the optimisation of the conversion process, which dominates overall production costs (with 35-65% of total costs). Also important is the efficient organisation of supply chain logistics; especially for the low energy density feedstocks such as wheat straw, densification early in the chain is required. In addition to conversion costs, labour costs and requirements, agricultural efficiency, and biomass yields are found to be key determinants of economic viability.

Chapter 5 assessed key economic, environmental and social issues pertaining to jatropha biofuels, based on almost 150 studies covering 26 countries. The assessment aimed to provide a state-of-the-art overview and identify knowledge gaps. So far, the total volume of jatropha production has remained small. Financial value and the number of jatropha projects have even declined since 2008. The economic analyses indicate minimal financial feasibility for projects. Yield increase and value addition (e.g., through utilising by-products) are necessary. Plantations seem to fare the worst, mainly due to the higher financial inputs used in a plantation setting and the still limited yield levels. Smallholders can only achieve financial feasibility in low-input settings and when opportunity costs are low. Unfortunately, hardly any Cost Benefit Analyses (CBA) are based on field data; partly due to a lack of long-running jatropha projects. The environmental impact varies greatly across locations. Most studies indicate significant greenhouse gas (GHG) benefits over fossil fuels; however, this is only achieved with limited inputs and no loss of high C-stocks. Furthermore potential loss of biodiversity is a risk if high conservation areas are converted. The determinants in Life Cycle Analyses (LCA) are yield, input level, by-products utilization, transesterification, transport distances, and previous land cover. Minimal negative social impacts have been revealed so far, but discontinuation of projects affects communities through income losses and fostering more negative attitudes towards new projects. If its financial feasibility is improved, jatropha can still become an option for sustainable energy production, GHG mitigation and rural development, especially through smallholder based production models. At the same time, successful implementation requires careful advance assessment of local circumstances, including the political climate, gender aspects and land ownership structures.

Chapter 6 demonstrated a methodology that quantifies key socio-economic impacts of the production of bioethanol in the Northeast of Brazil (NE), in particular the impact on GDP, imports and employment. In 2020 the value added by the sugarcane ethanol sector of the Northeast (NE) region reaches up to 2.8 billion US$ (BaU scenario), to almost 4 billion US$ (scenario A) and to 9.4 billion US$ (scenario B). The chapter showed that the large reduction of employment (114,000 jobs) due to the replacement of manual harvesting by mechanical harvesting can be offset by additional production and indirect effects. The total employment in the region by 2020 grows with 10% in scenario A (around 12,500 jobs) and 126% in scenario B (around 160,000 jobs). A large part of the GDP that is generated goes to those states where most industrial activities are located (due to indirect effects), most of the machinery, equipment, vehicles and services are provided by the Central South (CS). This means that if the current situation continues, any development in the producing states in the NE sector will not fully benefit the region because of the large dependency of the NE on the economic activities in the CS region. The use of an extended inter-regional IO model allowed quantification of the direct and indirect socio-economic effects at regional level and provided a deeper understanding of the linkages between regions. The application of the model to NE Brazil has demonstrated significant positive socio-economic impacts that can be achieved when developing and expanding the sugarcane-ethanol sector in the region under the conditions studied here, not only for the NE region itself but also for the economy of the rest of Brazil. When using inter-regional IO models, a large amount of intra and inter-regional data is needed and it is necessary to make assumptions on the dependability of interregional trading relationships. It is assumed that the economy and the inter-sectoral linkages stay the same in the given period of time, but this is a rather strong simplification. It is therefore recommended to use more updated IO tables when applying IO analysis for medium- to long-term time periods. Furthermore, Brazilian IO tables used could be improved by separating imports and household consumption to allow calculating the impacts on trade balance and the induced effects on the economy.

Chapter 7 aimed to compile a broad inventory of potential socio-economic impacts and to identify, apply and evaluate current options and indicators to measure those socio-economic impacts. Local impacts are often not discernible in data aggregated for the national level, especially where the sector is yet not fully developed. Furthermore, regional differences in socio-economic characteristics are significant, so that the impacts of bioenergy projects also differ substantially. Our analysis showed that it is essential to consider impacts at different scales, that is, the national, regional, and local levels. Background indicators (e.g. GDP in a region or unemployment rates), do not link directly to impacts of bioenergy, but can still provide useful information about the setting in which bioenergy projects are implemented. They can help identify potentially important issues (i.e., areas exhibiting risks of negative impacts or potential for positive impacts). Depending on the results of this check, more detailed indicators can be applied to give more precise insight into the nature and magnitude of potential local impacts. This means a staged approach is recommended: (1) a scan for each chosen area of concern, (2) in depth research in those specific areas of concern in which risks appeared during step 1. Furthermore, the study showed trade-offs between data accuracy and the practicability of data collection. This can vary per country and per feedstock. For new crops, the data is often not accurate and for low-income countries, such as Mozambique and Tanzania, the data is either not reliable or not available on a regional scale. More quantitative national, regional and local data is required to monitor impacts from biofuel production and conversion. Data collection could be facilitated by (inter)national bodies in collaboration with the private sector. Models that are used to quantify impacts on national and regional level for the long term, such as economic equilibrium and input-output models, need to be further developed using more accurate, and less aggregated data. Lastly, environmental indicators, should also be taken into account, further research into interdependencies with socio-economic impacts, and how to capture these with suitable indicators is recommended. It is also important to take account of standards and certification systems that are not specific for biofuels.

8.4 Main findings and conclusions

Based on the findings in Chapter 2-7, the following answers to the research questions and recommendations are given.

I. **What are the most important determinants of the socio-economic impacts of bioenergy systems in developing countries?**

The choice of the business model or type of production system is a major influence on socio-economic impacts. Different business models studied in this thesis are smallholder (hedge) systems, large scale plantations, or a combination of an estate and outgrowers ("nucleus estate model"). Smallholder models increase (household) income for a large group and can have spill-over effects with respect to knowledge and capacity building on conventional farming. Large-scale plantations offer more permanent employment, and can stimulate rural development, but also have higher risks of more profound negative environmental impacts and more risks for the local population if a project fails (e.g. due to too optimistic assumptions about yields and economic feasibility in the case of jatropha). Large scale plantations are more prone to land right conflicts, which is a generic problem for large land transfers in general (and in particular in Africa). Negative impacts could be minimized if land rights are returned to the original right-holders in case of project failure. Smallholder based biomass production hardly causes conflicts with land rights, although vulnerable groups can be affected if land availability is under pressure. Large scale production models can decrease food security if food production is lowered in case plantation employees stop cultivating their own food, or by displacement of food crops. This can be reversed by enabling employees to (continue to) cultivate food crops (in their spare time) and by avoiding displacement of food crops, for example by increasing agricultural productivity. Furthermore, increased income generation can increase food security. Large scale production schemes can also negatively influence food prices due to a large influx of (new) employees, this can be influenced by the company by avoiding sudden purchases of large amounts of food for their employees on local markets, so that these central bulk purchases do not aggravate inevitable local price increases caused by increased food purchases. Smallholder models can positively impact food security by generating additional income for smallholders and by providing education on improved agricultural techniques, but care should be taken so that food crops are not displaced.

The company values, or the way in which a model is implemented, also affect socio-economic impacts. The inclusion of corporate social responsibility values, for example adherence to international labour regulations, will lead to more positive socio-economic impacts. The company values can impact social wellbeing; providing education and training for employees leads to an improvement of social status and confidence levels. Negative health and safety impacts can be minimized by providing proper safety gear to both permanent and temporary workers. Furthermore, employing local laborers (where possible) will have more positive effects on (local) unemployment rates. Gender can be positively impacted if women get employment opportunities, or if special benefits are created for women such as paid maternity leave.

The level of development (national as well as regional) also influences socio-economic impacts of bioenergy systems. Economic characteristics that are related to the level of development are: average wage rates, land costs, opportunity costs of labour, unemployment rates, energy prices, infrastructural development, and alternative options (for income generation) in the area. This aspect is further elaborated in the answer to the next research question.

The economic performance of biofuel systems is an important determinant of socio economic impacts. Poor performance leads to project failures that negatively impact employment and income generation, and can also lead to negative social impacts such as reduced land access, food security and social well-being (lack of trust).

The key cost factors for first generation biofuels are feedstock production and to a lesser extent conversion and transport costs. For second generation biofuels, the conversion costs are the largest cost factor, but cost reductions in this area are expected in the future. The cost of feedstock production is mainly determined by the costs of inputs and management intensity in relation to the yield. Cassava and eucalyptus cultivation in an East African setting for example, have higher NPVs calculated for a lifetime of the system of 24 years, with intermediate inputs, compared to low inputs. This varies from negative to above 1000 $/ha for cassava (both with a wage rate of 2 $/day), and from a few hundreds to above 1200 $/ha for Eucalyptus. The difference is especially explained by higher yields. Biofuel derived from crops such as soy, sugarcane and palm are already competitive with fossil fuel alternatives (at oil prices over 100 U$/barrel) in situations their yields are high enough and high input systems are feasible. Depending on the setting; the country, location, level of inputs, end product and feedstock (and related to these variables the yield), biofuel production costs can vary from 5-45 US$/GJ. Soy, palm, eucalyptus and poplar are the feedstocks with the lowest costs, among the feedstocks considered in this thesis. Soy biodiesel can be produced for between 8-10 US$/GJ (in Argentina with different agricultural production systems), palm biodiesel between 8-22 US$/GJ (in Malaysia, Colombia, Indonesia), ethanol production from Eucalyptus between 16-20 US$/GJ or 12-30 taking uncertainty ranges into account (production takes place in Brazil and Mozambique), and biodiesel from poplar in Ukraine 14-23 US$/GJ (lower in 2030 compared to 2020) but including the uncertainty range 12-42 US$/GJ. In Indonesia lower production costs are achieved for oil palm plantations, compared to smallholder based oil palm production systems. Colombia can reduce feedstock costs and increase yield levels to similar levels as Malaysia and can produce oil palm biodiesel at similar costs (around 8 $/GJ), provided yields and conversion efficiencies are improved. For second generation feedstocks, conversion costs today come with a high uncertainty. If these costs can be reduced in the medium term, production costs of biodiesel (BtL) of around 12-16 US$/GJ can be achieved in Brazil and Mozambique.

The level of experience with feedstocks and conversion technologies is important because more experience reduces risks of project failures. Soy, sugarcane and oil palm have been cultivated for a long time and major efforts have been made to improve agricultural performance, for example by improving genotypes of soy and sugarcane. So, the knowledge level about these crops is high, which reduces the risks of failures. The knowledge level of cultivating switchgrass and jatropha is currently much lower. In Tanzania, there is considerable experience with cultivating jatropha as hedges, and cassava as a food crop, but its use as source for bioenergy is relatively new. In Mozambique there is considerable experience with sugarcane, cassava and palm, but much less with jatropha and soy. Biofuel conversion technologies for lignocellulosic feedstocks (e.g. gasification and Fischer Tropsch diesel or hydrolysis for ethanol) are still under development and limited commercial experience exist so far.

Selection of a suitable bioenergy system for a given setting, is crucial for achieving a sustainable project in both economic and social terms. What constitutes an optimal choice of a bioenergy system in a specific situation also depends on the financial resources of the investor/producer. Different feedstocks have different investment requirements. Perennials such as oil palm, jatropha and Eucalyptus, are only productive from approximately five to seven years onward. Annual crops such as cassava and soy need much less upfront investment, but need to be replanted every year (or 2 years). Sugarcane and switchgrass are cultivated in rotations of usually 7 and 15 years respectively, but can be harvested from the second year. Agricultural residues such as wheat straw need little investment. Furthermore, investment requirements of bioenergy systems also differ with the level of intensity of the chosen agricultural management system (ranging from low inputs of fertilizer use of irrigation and herbicides up to high input levels), and the level of mechanization. These characteristics in turn influence economic performance, in the sense that higher-intensity and more mechanized systems are associated with higher investment and input costs but also give rise to higher yields (per unit of land area) than manual low input systems. Hence, there are trade-offs to be considered by investors, between higher/lower investment of resources and higher/lower returns. What is most appropriate for one investor in a specific settting in this respect may not be optimal for another. Low resource levels of the investor/producer will limit the choice of feedstocks to jatropha or cassava, crops that require little investment and can be cultivated with low inputs. Jatropha is currently only feasible in situations where labour costs (including labour opportunity costs) are low, which means this crop is currently interesting for less developed countries/regions.

Crops such as jatropha and cassava still need improved harvesting and processing efficiencies in order to become more competitive with fossil petrol and diesel. Similarly, second generation biofuels still need efficiency improvements, especially in the conversion process. Improvement potentials also matter; crops or technologies for which large costs reductions are expected on foreseeable term may still prove attractive. A stable investment climate is however required to overcome initial higher costs.

Furthermore, risks of financial losses in cultivation are reduced if farmers can choose between <u>different markets</u> for their crops. Several crops such as palm, sugarcane, eucalyptus and cassava, have different markets they can supply, e.g. food, fuel, cosmetics, paper etc., sometimes even simultaneously such as soy (biodiesel as fuel and soy meal as food). This means the producer has the flexibility to target the market with the highest price. Jatropha is the only crop, out of the crops studied in this thesis, that has economic value only as fuel although there are multiple by-products that can be obtained such as fertilizer from seedcake, biogas or charcoal.

The <u>opportunity costs of labour</u> determines the choice for an optimal feedstock. For smallholders in East Africa, cultivating jatropha in a low input setting has marginal NPVs that are just positive if labour costs are 2 US$/day, but can be a few hundred dollars per hectare(over 24 years) if labour has zero costs (family labour). For a system where intermediate inputs are used this difference is even higher, and NPVs range from negative to over a thousand dollar. Similar large differences were found for cassava and eucalyptus cultivation (1000 or 6000 US$/ha). A wage rate of 2 US$/day in that region is normal, but limited labour opportunities may make a wage rate is less than 2 US$/day (temporary) attractive.

The <u>market</u> served by biofuel production also influences socio-economic impacts. Increased energy access is an important positive social impact but can only be realised if the bioenergy produced is used in the producing country. Solely targeting the export markets will not lead to increased energy access, but does have other socio-economic benefits such as employment, income generation and an improved trade balance. The domestic market could be targeted simultaneously with the export market as well, which can lead to more stable income for producers due to more diversified demand. It is also important to consider the market for by-products, such as electricity generation from sugarcane bagasse. Access to markets can be facilitated or constrained by logistic capacity though, which is a key issue in many developing countries.

Economic impacts and social impacts should be balanced. A project can perform really well in economic terms, but can result in negative social impacts such as resettlement of the local population or reduced food security due to displacement of food crops for biofuel crops. Also, if a project performs well in social terms but is not economically viable, there is a high risk of project failure with related negative impacts. Other examples are the payment of high wage rates which constitutes a positive socio-economic impact, but can as well lead to lower competitiveness of the produced biofuel. Moreover, applying high rates of mechanisation will lead to reduced employment, but also relatively higher-value jobs with high wages. This can be observed in NE Brazil, where employment is reduced with 10% (15,000 jobs) due to legislation that targets the phasing out of manual harvesting of sugarcane, but an increased mechanisation rate from 4 to 50% and related indirect effects can compensate for this effect, leading to an increase of employment with 10% (18,000 jobs) and even more if the whole of Brazil is taken into account. most jobs are created especially in other sectors with higher wage rates.

Furthermore, in making bioenergy investment decisions it is also important to consider what the realistic alternative development options are in a particular context. In regions with very few opportunities, even limited employment generation (and a low contribution to the (national) economy because all equipment has to be imported) can still generate highly valued impacts on household income and food security.

All this illustrates it is important to frame clear objectives and choose a bioenergy system that fits those goals, prioritising investment choices and their corresponding impacts in line with those objectives. In this way, difficult trade-offs can be successfully negotiated. For example, if the goal is to create rural employment, a minor contribution to national GDP could be accepted as long as a feedstock is chosen that fits this goal. But if the goal is to save national foreign exchange, or enhance energy security on a national scale, a feedstock needs to be chosen about which a lot of experience exists and that can be implemented on a large scale. Goals may however change, because they can be influenced by for example economic growth, modernisation of the agricultural system, or by new insights (generated by the projects) and should then be adapted accordingly.

II. What is the importance of different geographical scales (global, national, regional, local) on these impacts?

Trends and developments at different geographical levels influence the performance of bioenergy systems and they also interact with each other, which in turn result in interacting socio-economic impacts at several geographical levels.

<u>Global</u> oil and energy prices are mainly influenced by fossil oil production and demand and they influence economic competitiveness of bioenergy systems on a local scale. High oil prices lead to high fossil petrol and diesel prices and this will in turn lead to more

competitive biofuel prices, and increased NPVs for projects on a local scale (if feedstock selling prices are higher than additional costs for inputs such as fertilisers). On the other hand, once large amounts of biofuels are produced and sold, this could reduce high global oil prices. In periods of lower energy prices, alternative demand for bioenergy crops can also materialize. Swing (or flexible) production between food and fuel can stabilize prices and thus income. Examples are sugarcane that can be processed into sugar or ethanol, or palm oil that can be used as food or fuel. The competitiveness, and or economic viability of bioenergy projects depends largely on the economic and social attractiveness of alternative options and the reference energy system. These effects can be substantial in remote areas where fossil diesel and electricity from the grid are expensive and thus bioenergy is more competitive. However, this competitiveness can be reduced when cheaper energy becomes available via more efficient infrastructure or improved access to the electricity grid.

The costs, and therefore the competitiveness of biofuels also depend on the country where they are produced, that is, on factors at the national level. Differences in costs are, among other things, due to differences in wage rates, labour productivity, and climate conditions. Comparing the different countries which this thesis has taken into account, the lowest biofuel cost projections are obtained in Malaysia (palm) and Colombia (palm) in 2020, Indonesia (palm) and Argentina (soy). Poplar biodiesel (BtL) in Ukraine can be produced for 11-13 US$/GJ but in the medium term (2030). On a national level, the policy environment also has an influence on socio-economic impacts. Some indicators are relevant for one country but less relevant for another country, especially in areas of concern such as working conditions, land use rights, child labour, health and safety, and forced labour. For example, although the right to collective bargaining and to be a member of a trade union is widely accepted as an important indicator, its relevance varies considerably according to the national laws of different countries. In Argentina for example, monitoring of the law is more stringent than in Sub Saharan countries like Tanzania, and impacts on working and labour conditions are considered of much less importance in sustainability frameworks. Also the value that is placed by governments on social, economic, and environmental sustainability varies between countries.

The level of national - as well as regional - development also influence socio-economic impacts of bioenergy systems. Low developed regions are characterized by low technical capabilities and a low availability of (high) skilled labour. Implementing biofuel systems which require technical capabilities in such regions will impose higher risks of project failure and the negative socio-economic impacts that are associated with that. Similarly, in regions with few income generating opportunities such as rural areas, feedstocks that can be produced with little investment such as jatropha and cassava can still lead to positive impacts on income, so they can be specifically beneficial for smallholders but are less suitable for environments where labour availability constitutes a bottleneck. Implementation of 2nd generation biofuels generally requires large scale production and technological capabilities. Currently, these biofuels are not very suitable for rural environments in developing countries. They may be better suited to countries with higher levels of development such as Brazil, Argentina or South Africa. This pleads for ex-ante project assessments to provide a better understanding of national and regional (macro en meso) development conditions and underpin a good selection and implementation of bioenergy systems.

Producing sectors of different regions are linked and (indirect) impacts of bioenergy systems can become visible at different spatial levels, which can be visualized and quantified through input-output analysis. Bioenergy production in one region can stimulate for example producer sectors in another. In this thesis, the effects of regional inter-linkages was illustrated through an analysis of increasing sugarcane-ethanol production in the North East (NE) of Brazil, which was found to lead, with increased efficiency of the sugarcane-ethanol sector, to an additional 29,000 jobs in 2020 and an added value of US$ 1.1 billion. In addition, in the rest of Brazil also an additional 14,000 jobs can be created, and an added value of US$ 0.4 billion is generated, mostly due to the production of equipment in these regions (compared to 2010). Expanding the cultivation area of sugarcane in the NE can even lead to an additional 152,000 jobs in the expansion areas of the NE, 24,000 jobs in the traditional production areas of the NE and 65,000 in the rest of Brazil, which is more than the expected (direct) loss of jobs due to increased mechanization. It also leads to a total value of US$ 6.6 billion which can be added to the GDP of the NE of Brazil and US$ 2 billion to the GDP of the rest of Brazil. Another example is the strong reliance on imported equipment in low developed countries, which lowers the potential impact on national GDP. These linkages cover different geographical scales and effects are partly caused by the structure the (national and regional) economy and are thus important to take into account if policies are developed on a national level.

Local negative impacts such as a loss of access to land, or a loss of biodiversity due to land conversion, can have a detrimental effect on community services such as collection of firewood, medicines etc. On the other hand, employment generation on a local scale can have a large positive influence on local communities, even if these figures are not reflected in national employment rates. Other local (and regional) circumstances that can have an influence on socio-economic impacts are: the state of the infrastructure, the availability of (skilled labour) and access to services and goods. Land rights are generally organized on a national level, but the impacts occur on a local level. Disputes over compensation payments and reduced access to land, even after a project has discontinued, can lead to social unrest in the local communities. The transparency of land deals, regulation and monitoring should be enforced on a national level.

Food security is typically influenced by factors at all scales. On a local scale, food security can be impacted by conversion of land that was earlier used for cultivation of food crops leading to reduced food availability. This happened for example in Brazil where jatropha producers converted their food plots into plots for energy crop cultivation. But food security can also be impacted by an increase or decrease in food access as a result of changes in household income. Furthermore, macro trends in food prices also influence food security by eroding household purchasing power. Land use change (LUC) and indirect land use change (iLUC) can only be assessed on a global level. Global calculation models such as CGE or integrated assessment models, are therefore required to assess these various effects, but these models also require specific regional data. Further development on such model/data combinations will lead to a better understanding of food security and can identify effective measures to minimize risks of a decrease.

This thesis showed that it is essential to look at impacts emanating from different levels simultaneously: global, national, regional, and local. Global and regional trends can impact bioenergy systems at the local level, but at the same time bioenergy systems can have an impact on a global and/or regional scale. Furthermore, impacts on a local level are not always reflected in macroeconomic indicators and vice versa. Moreover, regional differences on socio-economic aspects can be large, and thus the potential regional impacts of bioenergy projects as well. The differences in the biofuel production costs for the fuel production pathways indicate the importance of using specific settings that take into account local circumstances. Assessing (investment proposals for) a bioenergy project should always be done in the context of the region in which it is implemented. At the same time, it is useful to compare (plans for) bioenergy projects with similar feedstocks, placed in different regions.

III. What methodologies and tools can be developed to measure these socio-economic impacts?

Economic feasibility, the impact on local prosperity, labour and working conditions, food security and land ownership and rights, are important socio-economic areas of concern that can assist to evaluate local socio-economic impacts of bioenergy projects in developing countries. Field surveys on a local level can already tackle many (local) impacts such as impacts on working and labour conditions, employment generation and wages. Economic feasibility of projects is not an issue in current certification schemes. However, especially in the case of projects that use feedstocks for which relatively little commercial experience exists (Jatropha, lignocellulosic feedstocks for biofuels), the risk of bankruptcy is relatively high, with major negative (socio-economic) impacts on the local population. Including more economic feasibility-related indicators in sustainability certification standards may help to reduce the number of disrupted projects. Indicators such as net present value, internal rate of return capture profitability if used in a cost benefit analysis. The underlying assumptions of these calculations should be provided as well, so that cross-checking with the latest knowledge is possible but also to enable a sensitivity assessment of the economic performance for variations in discount factor, timeframe, and cost factors. Implementation of a project should also depend on comparing NPVs to alternatives for selling the feedstock or cultivating other crops.

The impact on local prosperity can be assessed by analyzing the impact of the bioenergy system on; employment figures (with a differentiation between permanent and temporary contracts), by measuring community investments by companies, improved access to energy, by checking wages and employment benefits, maximum working hours and freedom of association and the provision of personal protective equipment (for permanent and temporary workers). Furthermore, food security that is impacted by bioenergy companies can be assessed by measuring: land that is converted from staple crops, (perceived) food availability changes, changes in time spent on subsistence agriculture, and employment and wages. Land rights issues can be measured by checking whether the company has a legal (unchallenged) title, which area of land is customary, public or community land, which area of land that is currently under dispute. Furthermore, the (possible) investments made by bioenergy projects in the region, for example in health care, education facilities, infrastructure etc, can be evaluated and should be taken into account. But not all investment remains in the country; especially when large proportions of the required technologies, equipment and human capital have to be imported, the net short-term effect on the GDP of a country will be lower. However, bioenergy investments can also be a stepping stone for increased development of the region in the longer term. Further development of indicators to measure more subjective social well-being aspects in a systematic way is recommended.

Indicators for socio-economic impacts at a national, regional and global level are, for example, bioenergy sector contribution to national GDP (value added) (also regional), total amount of revenue collected from the bioenergy sector, effects on imports and exports, food prices and use of production factors. Key methodologies for assessing these indicators are computable general equilibrium (CGE) models and input-output (IO) analysis. IO analysis can be used to quantify, for example, the employment effects and the total value added generated by the bioenergy sector. Particularly, an extended inter-regional IO model can quantify direct and indirect socio-economic effects at regional level and can provide insight into the linkages between regions. Applying such a model requires to be able to implement a new sector in national input-output tables as well as the availability of regional input-output tables. It also requires fieldwork to obtain supplementary regional data. CGE models are important tools not only to analyse the economy-wide effects of increased biofuel production but also to study the effects of measures that help minimize displacement and competition between food and energy production. However, a key weakness of CGE models is the high level of aggregation in terms of e.g. regions and crops.

Therefore, a key component in better understanding impacts, particularly the interaction between different scales, and in providing more comprehensive insights into socio-economic impacts is the combination of models at different scales. That is, local analyses and data collection should be linked to regional and global assessments and vice versa. This can be done for example by local verification of the model outputs, or by including global price effects in NPV calculations on project level. This is relevant for both existing production (e.g. for certification) and ex-ante analysis, where the insights can be used to select and implement the most suitable bioenergy systems given existing (policy) goals and biophysical and socio-economic characteristics of the region in question.

In addition, background indicators, such as the GDP and the level of unemployment in a region, do not link directly to impacts of bioenergy, but can provide a ‘snapshot’ of the relative development of a region or country in which bioenergy projects operate. They can help identify potential important areas of concern (associated with negative or positive impacts) beforehand, such as food security or gender issues. In this way, they can help to determine whether the area of concern, e.g. food security, is an important issue to consider in the project region. After this superficial check, more detailed indicators can be applied, if necessary, to give insight in the extent and the exact nature of the potential (local) impact. Working conditions in Argentina for example are well monitored and regulated by law, but this is much less the case in Tanzania. Thresholds have to be determined, but benchmarking the local situation to global averages would provide a first starting point.

8.5 Recommendations

8.5.1 Recommendations for further research

- This thesis focused on socio-economic impacts, but for a comprehensive overview, environmental impacts on topics such as water, biodiversity, GHG emissions etc., and how these are and can be inter-linked with socio-economic impacts should also be taken into account. For example, a high water consumption of biomass feedstocks, could lead to high yields but can also negatively affect water availability for the local population. Additional research on these type of interdependencies is recommended.

- Many indicators are currently based on qualitative data, which is sufficient for themes such as working conditions, health issues and land use conflicts. But other, more complex, multidimensional themes such as food security, land competition or economic development of e.g. a region, that link with many different factors, need more comprehensive methodologies such as Input/output Analyses or General Equilibrium models. Further development of these methodologies is recommended. Furthermore, more methodologies and (global) models, based on quantitative data, need to be developed to gain better insight in socio-economic impacts on the long term such as general equilibrium models for food security and input-output models to analyse impacts on GDP and employment. More quantitative indicators are ideally required to improve assessment of social impacts and effects on environment.
- The diversity of taxes and subsidies between different countries has not been studied in this thesis. However, such financial regimes affect the economic performance of bioenergy systems, and have macro-economic effects, and should therefore be taken into account.

8.5.2 Market and policy recommendations

- Increased attention should be given to making the right choices for a bioenergy system, taking into account local circumstances but also national and regional development levels and characteristics. The choice will depend on the level of technology and input that is required for the feedstock, on the level of experience and on the level of development in the region. Choice of location must be based on information about climate conditions, current land use and also by socio-economic conditions in a region aspects such as (skilled) labour availability and available infrastructure. An ex-ante analysis of a range of cultural and socio-economic aspects on location is recommended prior to implementation. This can provide insights in potential key areas of concern. So, the following steps should be considered (in between these steps, there should be an ongoing evaluation of new information e.g. with more accurate data):
    1. Set and clearly define the objective(s) of a biofuel project or programme.
    2. Define or select the location (and thus the level of development).
    3. Determine suitable biofuel options and production scales (appropriate for the location)

4. Apply a first scan for each area of concern for the different options.
5. Perform an in depth ex-ante impact analysis (with local, regional and national data) on potential areas of concern.
6. Choose the most optimal bioenergy system, followed by (gradual) implementation.
7. Monitor the bioenergy system (using suitable indicators) so that possible adjustments can be made over time before upscaling the system.

- Gradual upscaling by first implementing (small) pilot projects will enable valuable learning-by-doing, and limit possible negative socio-economic effects due to project failures. Incremental project development trajectories offer more flexibility for experimentation with different options (e.g. for by-product valorisation) and for changes in strategy in the course of implementation.
- This thesis clearly indicates that inclusion of socio-economic aspects in sustainability frameworks for bioenergy is desirable, not only in order to avoid the benefits for climate change and global energy security from being offset by detrimental effects on local communities and livelihoods, but also in order to stimulate the maximization of potential socio-economic benefits of (sustainable) bioenergy schemes. This is especially relevant for projects that use feedstocks or technologies with relatively little commercial experience (Jatropha, lignocellulosic feedstock conversions). For such projects, the risk of bankruptcy is relatively high, with major negative (socio-economic) consequences for the local population. Further development of indicators that can measure social well-being for employees and for the local population, is recommended.
- The bioenergy sector is closely linked, and often an integral part of, the agricultural sector. Thus, policies that support sustainable bioenergy should be well embedded into an overarching agricultural strategy. Key is that better agricultural management can avoid displacement of food production by biofuels through higher overall efficiency of farming systems. Generally, this leads to increased and diversified incomes in rural economies.
- Certification could act as a tool to improve the overall management of the agricultural sector. National policies in particular can play a role in deploying sustainability criteria (for the whole agricultural sector), in improved monitoring on various socio-economic aspects such as food security, preferably on a regional scale (in the developing countries themselves), in implementing pilot projects and by showing long-term commitment to these projects. Real and sustained field experience from pilot projects is important to obtain best practice experience and reduce future risk for the (future) bioenergy producers.

- Availability and reliability of data is a bottleneck for analysing socio-economic impacts. Most economic indicators are based on robust methodologies, but accurate data is often lacking and therefore it is hard to use the indicators effectively in practice. For many developing countries, national statistics are often unreliable; poorly available, often outdated or inaccurate.
    - Government bodies or international organisations could collect and monitor the data which would provide for example the basic data for the background indicators.
    - More data collection is required on all levels (national, regional and local). The global datasets should be improved in terms of accuracy, spatial resolution, consistency, classification, ground-truthing, updating and continuation. Underlying assumptions in economic calculations should also be provided. The type of data that is required includes statistical data on socio-economic conditions on local, regional and national levels. Additional socio-economic data is required on economic aspects such as regional GDP and Input/Output tables, on employment and local prosperity aspects such as total workforce and (un)employment, education levels and access to electricity, on food security aspects such as regional food security indices, and on land aspects such as spatially explicit zoning maps and community land access. Baseline studies including these data are required to be able to track performance over time.
    - More harmonization in economic assessment methodologies should be facilitated as well. The length of the chosen timeframes and the discount factor can be crucial. Furthermore, some assessors only use average cost units but do not perform a thorough cost-benefit analysis in which NPV, internal rate of return and Pay back periods are calculated.
- The conversion of feedstocks to biofuels should preferably take place in the producing countries themselves, because of the additional added value and positive effects on the national economy of a country, depending on the imports of equipment, technology and inputs. But the domestic and international market for biofuels can be developed simultaneously in mutual supportive fashion, which can enhance economies of scale and learning effects. Furthermore, an initial focus on one market can lead towards growth in the other; production of biofuel for export in the first instance can enable the sector to grow and e.g. a blending mandate can then gradually be implemented to use the biofuel also for the domestic market.

- Minimizing the risk of bioenergy project failures should receive a high priority. For projects at a very small scale, challenges can be minimized by paying sufficient attention to capacity building among project implementers and local communities that are the users of the new energy services. For larger projects involving outsider investors, sufficient agronomic expertise and knowledge about the local culture is equally essential prior to investing in a relatively new sector such as bioenergy in developing countries. Gradual upscaling is recommended to facilitate learning by doing, capacity building and external support networks. Economic feasibility can be improved over time by adding value to by-products and investing in more efficient conversion technologies.
- Governments need to ensure that companies that invest in the agricultural sector and acquire land, include an exit strategy into their investment plans, with clear regulations on returning land rights to the original land holders if their project has to discontinue.
- A country should not focus on one specific bioenergy crop, but facilitate multiple options, preferably crops that can serve multiple markets. Soy, cassava and sugarcane can serve the food and fuel market at the same time. 2nd generation feedstocks such as eucalyptus and poplar can (partly) target the paper and fuelwood markets, until 2nd generation conversion technologies are competitive. Furthermore, each country has several local crops that could be used as bioenergy, this would be preferred over the introduction of cultivation of ‘new’ crops on a large scale.

Samenvatting in het Nederlands

Wereldwijd stijgt de vraag naar energie, die voor verschillende doeleinden gebruikt wordt (transport, verwarming, elektriciteit etc.). Het gebruik van fossiele brandstoffen heeft negatieve gevolgen, zoals de uitstoot van broeikasgassen, die leiden tot klimaatverandering. Om broeikasgasemissies te reduceren kan hernieuwbare of duurzame energie gebruikt worden met als bron zon, wind, water of biomassa. Het voordeel van het gebruik van biomassa (als biobrandstoffen) is dat het bijdraagt aan het tegengaan van klimaatverandering, maar tegelijkertijd ook kan leiden tot andere positieve effecten zoals rurale ontwikkeling, verhoging van de werkgelegenheid en groei van het Bruto Binnenlands Product (BBP). Het totale technische biomassapotentieel is maximaal 500 EJ/jaar, en een groot gedeelte van dit potentieel bevindt zich in ontwikkelingslanden.

De productie van de grondstoffen voor biobrandstoffen, de gewassen, kan positieve effecten hebben, zoals een verhoogd en gediversifieerd inkomen uit de landbouw, meer werkgelegenheid in rurale gebieden, een algemene verbetering van het bestaansniveau van de lokale bevolking en een verbeterde toegang tot energie. De productie en het gebruik van biobrandstoffen kunnen echter ook negatieve gevolgen hebben, zoals een verlies van biodiversiteit, ontbossing, negatieve effecten op voedselzekerheid en landrechten, en een onevenwichtige verdeling van inkomsten en kosten. Bio-energiesystemen kunnen dus zowel positieve als negatieve effecten teweegbrengen en hun inzet moet in balans zijn met milieudoelstellingen- en sociale en economische doelstellingen. Deze doelstellingen zullen op verschillende schaalniveaus (zowel plaats- als tijdafhankelijk) vastgesteld moeten worden. Ook zijn verschillende criteria en methoden nodig voor de beoordeling van de duurzaamheid van de systemen, zodat adequate en goed geïnformeerde beslissingen genomen kunnen worden. Er bestaat tot nu toe nog veel onduidelijkheid over de specifieke omstandigheden waaronder bio-energieproductie en -gebruik tot positieve dan wel negatieve sociaaleconomische effecten en milieueffecten kunnen leiden. Tegelijkertijd is de relevantie van deze effecten door de groeiende productie en handel steeds groter geworden.

Certificeringssystemen kunnen bijdragen aan verduurzaming van de productie van biobrandstoffen. Hoewel binnen deze systemen het accent vaak niet op de sociaaleconomische effecten ligt, zijn deze wel belangrijk. Er is een tekort aan empirische data op lokaal niveau, mede omdat het vaak ontbreekt aan de mogelijkheden (zowel tijd als geld) in ontwikkelingslanden om deze data te verzamelen. Ook zijn de omstandigheden in ontwikkelingslanden in termen van infrastructuur, de grootte van landbouwbedrijven, e.d., erg verschillend van die in de westerse landen waar deze certificeringssystemen voor het overgrote deel worden ontwikkeld.

Dit proefschrift heeft als doel bij te dragen aan een verbeterde analyse en kwantificering van sociaaleconomische effecten van biobrandstoffen in ontwikkelingslanden. Het onderzoek analyseert deze effecten in relatie tot schaalgrootte, het type biomassa/bio-energie dat geproduceerd wordt, de contextuele omstandigheden en belangrijke karakteristieken van verschillende productiesystemen.

De volgende onderzoeksvragen zijn geformuleerd:

I. Wat zijn de belangrijkste bepalende factoren van de sociaal-economische gevolgen van bio-energie systemen in ontwikkelingslanden?
II. Wat is het belang van de verschillende geografische schalen (lokaal, regionaal, nationaal, mondiaal) op deze effecten?
III. Welke methoden en instrumenten kunnen worden ontwikkeld om deze sociaaleconomische effecten te meten?

Deze onderzoeksvragen worden behandeld in hoofdstuk 2 tot en met 7. Elk hoofdstuk evalueert de sociaaleconomische effecten van biobrandstoffen in verschillende contexten en op verschillende geografische schalen. Op basis van de bevindingen in hoofdstuk 27 kunnen de onderzoeksvragen als volgt beantwoord worden:

I.

De volgende factoren hebben een grote invloed op de sociaaleconomische effecten: het gekozen bedrijfsmodel (bijvoorbeeld kleinschalige boeren versus grote plantages), de bedrijfswaarden (bijv. maatschappelijk verantwoord ondernemen), het economisch ontwikkelingsniveau van de regio en daarmee samenhangende economische karakteristieken, de economische prestatie van de biobrandstofketen (om projectmislukkingen te voorkomen), de mate van ervaring met de gewassen en de conversietechnologie in een regio, de financiële middelen van de investeerder of producent, het gekozen gewas en de eventuele verschillende markten die beschikbaar zijn (in verband met mogelijkheden voor hogere prijzen en dus risicospreiding), de beschikbare alternatieven voor het verwerven van inkomen voor de lokale bevolking in de productieregio en de markt die gekozen wordt voor het eindproduct (voor export, binnenlands gebruik of allebei).

De belangrijkste kostenfactoren voor biobrandstoffen van de eerste generatie zijn de productie van grondstoffen en in mindere mate conversie -en transportkosten. Voor biobrandstoffen van de tweede generatie zijn de conversiekosten de grootste kostenpost, alhoewel de toekomst worden kostenbesparingen verwacht door leereffecten. De kosten van de grondstofproductie worden voornamelijk bepaald door de kosten van de agrarische inputs en de intensiteit van het agrarisch management, hetgeen gerelateerd is aan de opbrengst per hectare (ha). Het verbouwen van cassave en eucalyptus in de Oost-Afrikaanse context levert meer op in termen van netto contante waarde bij een relatief hogere input-intensiteit. Afhankelijk hiervan varieert de opbrengst voor cassave van een negatief bedrag tot boven de 1000 US$/ha (bij een dagloon van 2 US$), en voor Eucalyptus van een paar honderd US$ tot boven de 1200 $/ha. Het verschil wordt veroorzaakt door de hogere opbrengst per ha. Jatropha levert alleen winst op als de arbeidskosten laag zijn of als er weinig alternatieven zijn om een inkomen te genereren. Biobrandstof gemaakt van gewassen zoals soja, suikerriet en palm zijn al concurrerend met fossiele brandstoffen (bij een olieprijs van meer dan 100 U$/vat) op plaatsen waar systemen met intensieve productiemethoden en hoge opbrengsten per ha haalbaar zijn. Afhankelijk van de context, het land, de locatie, de input-intensiteit, het eindproduct en het gewas (en in verband met deze variabelen; de oogst/opbrengst), variëren de productiekosten van de biobrandstoffen die in dit proefschrift zijn behandeld van 5 tot 45 US $/GJ. De productiekosten van biobrandstoffen van de eerste generatie in 2010 zijn in dit proefschrift berekend tussen de 5-45 US$/GJ, in 2020 tussen de 10-35 US$/GJ, en van biobrandstoffen van de tweede generatie tussen de 17-27 US$/GJ in 2020 en tussen de 14-23 US$/GJ in 2030. Op basis van de dit proefschrift gepresenteerde analyse zijn zoja, oliepalm, eucalyptus en populier de gewassen met de laagste kosten. Biodiesel op basis van sojaolie kan geproduceerd worden tussen de 8-10 US$/GJ (in Argentinië, waarbij verschillende productiesystemen meegenomen zijn in de analyse), biodiesel op basis van palmolie tussen de 8-22 US$/GJ (in Maleisië, Colombia en Indonesië), ethanol uit Eucalyptus tussen de 16-20 US$/GJ - of tussen de 12-30 US$/GJ als de onzekerheidsmarges meegeteld worden - (in Brazilië en Mozambique), en biodiesel van populier in de Oekraïne tussen de 14-23 US$/GJ (lager in 2030 vergeleken met 2020) of tussen de 12-42 US$/GJ inclusief de onzekerheidsmarges. Economische en sociale effecten moeten vaak tegen elkaar worden afgewogen. Een project kan goed presteren op economisch vlak, maar kan negatieve sociale gevolgen hebben. Ook als een project op korte termijn goed presteert in sociaal opzicht, maar economisch niet rendabel is, bestaat een hoog risico op mislukking van het project met bijbehorende negatieve effecten. Daarom is vaak sprake van trade-offs tussen deze effecten. Bij het nemen van investeringsbeslissingen in bio-energieprojecten is het ook belangrijk om te overwegen wat de realistische alternatieve ontwikkelingsopties zijn in een bepaalde context. In regio's met zeer weinig mogelijkheden om inkomen te genereren kan zelfs een beperkte toename van de werkgelegenheid en een lage bijdrage aan de (nationale) economie waardvolle effecten creëren op het inkomen van huishoudens en positief uitwerken op de voedselzekerheid.

Dit alles illustreert dat het belangrijk is om duidelijke doelstellingen te formuleren en een bio-energiesysteem te kiezen dat bij die doelen past. Investeringskeuzes en de bijbehorende effecten moeten geprioriteerd worden in lijn met deze doelstellingen. Op deze manier kunnen complexe afwegingen beter worden gemaakt. Als het doel bijvoorbeeld is om rurale werkgelegenheid te creëren, dan kan een minimale bijdrage aan het BBP geaccepteerd worden, zolang er tenminste een gewas en teeltmethode geselecteerd wordt dat bij deze doelstelling past. Echter, als het doel is om op grote schaal energiezekerheid te verkrijgen of om de handelsbalans te verbeteren door het uitsparen van olie-importen, dan zal een gewas geselecteerd moeten worden waar men veel ervaring mee heeft en dat op grote schaal geïmplementeerd kan worden. Doelen kunnen echter veranderen, omdat deze kunnen worden beïnvloed door bijvoorbeeld economische groei, modernisering van het agrarische systeem of en moeten dienovereenkomstig worden aangepast.

II.

Dit proefschrift laat zien dat het essentieel is om tegelijkertijd te kijken naar de effecten die plaatsvinden op verschillende geografische schalen: mondiaal, nationaal, regionaal en lokaal. Mondiale en regionale trends kunnen bio-systemen beïnvloeden op lokaal niveau en tegelijkertijd kunnen lokale bio-energiesystemen een impact hebben op mondiale en/of regionale schaal. De lokale effecten van biobrandstof projecten komen ook niet altijd tot uiting in de macro-economische indicatoren en vice versa. Bovendien zijn in veel landen de regionale verschillen tussen verschillende sociaaleconomische aspecten, zoals werkgelegenheid en gemiddeld inkomen, groot en daarmee ook de mogelijke regionale effecten van bio-energieprojecten.

Op mondiaal niveau kunnen olie- en energieprijzen de economische prestaties van lokale bio-energie systemen beïnvloeden. Op nationaal niveau zijn dat de hoogte van de lonen, de arbeidsproductiviteit en het klimaat. Ook het politieke klimaat en het ontwikkelingsniveau van het land of de regio waarin het project geïmplementeerd wordt en de daarmee samenhangende factoren zoals bijvoorbeeld de beschikbaarheid van opgeleid personeel, hebben invloed.

Productiesectoren in verschillende regio's van een land zijn meestal met elkaar verbonden en dit heeft invloed op de (in)directe effecten van een bio-energiesysteem. Deze (in)directe effecten kunnen inzichtelijk gemaakt worden door een interregionale input-outputanalyse. In dit proefschrift is dat geïllustreerd voor een analyse van de suikerriet-ethanol sector in Noordoost Brazilië. Indien deze sector efficiënter zou produceren, dan kunnen in 2020 bijna 30.000 banen gecreëerd worden en een toegevoegde waarde gegenereerd worden van meer dan 1 miljard US$. In de overige delen van Brazilië kunnen ook nog eens zo'n 14.000 banen gecreëerd worden. Dit komt vooral doordat de productie van machines en andere inputs die de sector nodig heeft, plaatsvindt buiten Noordoost Brazilië. Uitbreiding van de suikerriet-ethanolsector in Noordoost Brazilië kan indirect zelfs tot meer dan 200.000 banen leiden, wat meer is dan het verwachte directe banenverlies door mechanisatie in de sector. Het importeren van apparatuur in ontwikkelingslanden vanuit andere landen, zal een lager effect op het Bruto Binnenlands Product (BBP) dan wanneer deze apparatuur in het land zelf gemaakt zou worden. Dit soort indirecte effecten, die dus op verschillende schaalniveaus plaatsvinden, worden deels bepaald door de structuur van de nationale en regionale economie en zijn belangrijk om mee te nemen bij beleidsontwikkeling op nationaal en regionaal niveau.

De verschillen in de productiekosten van biobrandstoffen tussen locaties, benadrukken het belang van het gebruik van goede specifieke lokale gegevens. Het beoordelen van een bio-energie project of investeringsplan, moet altijd worden gedaan met kennis van de context van de regio waarin het zal worden uitgevoerd. Tegelijkertijd is het nuttig om bio-energieprojecten of plannen daarvoor, te vergelijken met soortgelijke bio-energieprojecten die dezelfde gewassen gebruiken, maar bijvoorbeeld in andere gebieden.

III.

Belangrijke aandachtsgebieden voor de evaluatie van lokale sociaaleconomische effecten van bio-energieprojecten zijn: de economische haalbaarheid, de impact op de lokale welvaart, de arbeidsomstandigheden, voedselzekerheid en landrechten. Lokaal veldonderzoek kan voor veel effecten inzicht verschaffen bij een evaluatie, zoals bij effecten op de arbeidsomstandigheden, werkgelegenheid en lonen. De economische prestaties van projecten worden meestal niet meegenomen in de huidige certificeringsschema's. Echter, vooral voor projecten die op grotere schaal gewassen of technologieën gebruiken waar nog niet veel ervaring mee is opgedaan, bijvoorbeeld met jatropha of conversie technologieën voor vloeibare brandstof uit houtachtige gewassen, is het risico op een faillissement relatief hoog. Dit heeft grote negatieve sociaal-economische gevolgen voor de lokale bevolking. Indicatoren zoals netto contante waarde en intern rendement kunnen verwachte winstgevendheid weergeven als ze in een kosten-baten analyse worden gebruikt. De onderliggende aannames zoals opbrengst per hectare, rentevoet enzovoorts, die gebruikt zijn moeten echter ook transparant vermeld worden, zodat men het realiteitsgehalte van dit soort indices adequaat kan beoordelen, eventuele nieuwe kennis kan toetsen en een gevoeligheidsanalyse mogelijk kan maken.

Effecten op de lokale welvaart kunnen beoordeeld worden door het meten van de invloed van het project of bedrijf op werkgelegenheidscijfers, inclusief onderscheid tussen vaste en tijdelijke contracten. Verder kan de invloed gemeten worden door het beoordelen van investeringen in de gemeenschap door de bedrijven en projecten; door het controleren van de lonen en arbeidsvoorwaarden, van de maximale werktijden en vrije toegang tot vakbonden; en door het beschikbaar stellen van beschermingsmiddelen voor vaste en tijdelijke werknemers. De invloed op de voedselzekerheid kan gemeten worden door te kijken naar: de hoeveelheid land dat is omgezet van voedselgewassen naar biobrandstofgewassen, de veranderingen in voedselzekerheid zoals die door de lokale bevolking worden opgemerkt, veranderingen in arbeidstijd die aan het verbouwen van voedselgewassen voor huishoudelijke consumptie besteed wordt, en werkgelegenheid en lonen. De effecten op landrechten kunnen gemeten worden door te controleren of het bedrijf juridisch onbetwiste eigendomspapieren heeft, welk gedeelte van het land openbaar of gemeenschappelijk is, en welk gedeelte momenteel ter discussie staat. Verder kunnen eventuele investeringen door het project of bedrijf in de regio, zoals in de gezondheidszorg, onderwijs en infrastructuur, expliciet beoordeeld en meegenomen worden.

Een belangrijke component in het beter begrijpen van de sociaaleconomische effecten is met name de interactie tussen de verschillende geografische schalen. Dat wil zeggen; de lokale analyses en het verzamelen van gegevens moet worden gekoppeld aan regionale en globale evaluaties en vice versa. Dit kan bijvoorbeeld gebeuren door lokale verificatie van model-outputs, of door het opnemen van (geobserveerde of geprojecteerde) wereldwijde prijsvariaties in netto contante waarde berekeningen op projectniveau. Dit is relevant voor zowel bestaande productie (bijv. voor het doel van certificatie) als ex-ante analyses. De inzichten kunnen worden gebruikt om de meest geschikte bio-energiesystemen te selecteren en implementeren, rekening houdend met bestaande (beleids) doelen, risico’sen de biofysische en sociaaleconomische kenmerken van de regio.

Achtergrondindicatoren, zoals het Bruto Binnenlands Product en de werkloosheid in een regio, zijn niet direct te koppelen aan effecten van bio-energie, maar kunnen wel een ‘snapshot' van de relatieve ontwikkeling van een regio of land bieden waar bio-energieprojecten (willen) opereren. Ze kunnen helpen bij het identificeren van potentieel belangrijke aandachtsgebieden, zoals voedselzekerheid. Zo kunnen zij helpen bepalen of het aspect in kwestie van belang is in het projectgebied. Na deze snelle scan kunnen, indien nodig, meer gedetailleerde indicatoren worden toegepast om inzicht te krijgen in de omvang en de precieze aard van de mogelijke (lokale) impacts. Drempelwaarden die de condities in lokale situaties goed weerspiegelen moeten uiteindelijk worden vastgesteld, maar een eerste uitgangspunt zou gevormd kunnen worden door een vergelijking van de lokale situatie met mondiale gemiddelden.

Op basis van het werk in dit proefschrift wordt aanbevolen verder onderzoek uit te voeren naar:

- De mogelijke koppelingen tussen milieueffecten van biomassa en bioenergie-productie met sociaaleconomische effecten.
- De complexe thema's zoals voedselzekerheid, en dan met name door het aanvullen van de kwalitatieve indicatoren met kwantitatieve, alsmede door het verder ontwikkelen van methoden die gebaseerd zijn op input-output- en algemene evenwichtsmodellen.
- De diversiteit in belastingen en subsidies in de verschillende landen op het gebruik of op de productie van (bio)brandstoffen, zodat deze expliciet meegenomen kunnen worden in de economische berekeningen en macro-economische effecten.

Aanbevelingen voor beleid en marktontwikkeling:

- Voor toekomstige implementatie dient vooraf zeer explicieit aandacht te worden gegeven aan het maken van de keuze voor het juiste bio-energiesysteem in relatie tot de verwachtte impacts. Dit zou volgens de volgende stappen gedaan kunnen worden:
    - Stel een set duidelijke doelstellingen op voor het biobrandstofproject of -programma.
    - Definieer of selecteer de locatie (en stel dus alsmede het ontwikkelingsniveau vast).
    - Stel de in eerste instantie geschikte opties voor biobrandstofsystemen en de productieschaal vast passend bij de regio.
    - Maak een scan van de effecten op de verschillende aandachtsgebieden voor de verschillende bio-energie ketens.
    - Maak een diepgaande analyse met gebruik van lokale, regionale en nationale gegevens van de aandachtsgebieden die belangrijk zijn gebleken in voorgaande stap.

  - Kies het meest optimale bio-energiesysteem en implementeer dit geleidelijk.
  - Monitor dit systeem met behulp van geschikte indicatoren, zodat eventueel aanpassingen gemaakt kunnen worden en alvorens tot verdere opschaling wordt overgegaan.
- Geleidelijke opschaling door het eerst implementeren van kleinere pilot projecten maakt 'learning by doing' mogelijk en verkleint de kans op het mislukken van een project
- Het is wenselijk om sociaaleconomische aspecten integraal in duurzaamheidskaders in te passen. Indicatoren voor het meten van het welzijn van werknemers en de lokale bevolking moeten verder ontwikkeld worden.
- De bio-energiesector is nauw verbonden met de agrarische sector. Beleid gericht op duurzame bioenergie zal dan ook gekoppeld moeten zijn met agrarische sector als geheel.
- Systemen voor duurzaamheidscertificering kunnen helpen als middel om de agrarische sector te verbeteren. Nationaal beleid speelt hierbij een grote rol door het vaststellen van duurzaamheidscriteria, het monitoren van verschillende sociaaleconomische aspecten, het implementeren van pilotprojecten en het laten zien van langdurige toewijding en inzet.
- De gebrekkige beschikbaarheid en betrouwbaarheid van data voor bepaling van sociaal-economische impacts is vaak problematisch. Internationale organisaties en private initiatieven zouden meer en betere data moeten verzamelen op alle niveaus (lokaal tot mondiaal) en de onderliggende aannames zoals opbrengst per hectare, rentevoet enzovoorts, zouden ook beschikbaar moeten zijn. Economische analysemodellen zouden geharmoniseerd moeten worden en gebaseerd op geverifieerde accurate (veld)data.
- De conversie van de grondstoffen naar biobrandstoffen zou idealiter plaats moeten vinden in het land zelf. Er kan synergie uitgaan van het tegelijk bedienen van de interne en externe markt, bijvoorbeeld vanwege schaalvoordelen en verschillende leereffecten. Ook kan een initiële focus op de ene (export) markt zorgen voor een impuls in de ontwikkeling van de interne markt.
- Het minimaliseren van risico's op het mislukken van projecten zou een hoge prioriteit moeten krijgen. Kleine projecten zouden veel aandacht moeten besteden aan opbouw van lokale kennis en competenties. Grotere projecten zouden voor hun implementatie expertise over het gewas en over culturele aspecten in kunnen winnen. Economische prestaties van de systemen kunnen

verbeterd worden door verwaarding van bijproducten en door te investeren in efficiëntere conversie-technologieën.

- Overheden zouden een uitgewerkt plan voor een exit-strategie voor investeerders verplicht moeten stellen, zodat landrechten teruggegeven worden aan oorspronkelijke eigenaren indien het project niet doorgaat of voortijdig wordt afgebroken.
- Een land zou zich niet op één specifiek bio-energiegewas moeten richten, maar op verschillende gewassen die idealiter verschillende markten kunnen bedienen. Ook verdienen, indien beschikbaar, lokaal bekende gewassen eerder de voorkeur in plaats van uitheemse soorten waarmee geen ervaring bestaat.

Muhtasari katika Kiswahili

Mahitaji ya nishati ulimwenguni pamoja na huduma husika, yanaendelea kongezeka. Uchimbaji na utimizi wa mafuta unachangia pakubwa katika uzalishaji wa gesi chafu ulimwenguni. Kuna mbinu tofauti za kupunguza uzalishaji huu wa gesi chafu, moja wapo ikiwa utimizi was nishati mbadala. Kunazo njia mbali mbali za kuzilisha nishati hizi, kati yazo ni kwa kutumia jua, upepo, mvuke utokao ardhini na majani au kwa kimombo biogas.

Faida kubwa za utumizi wa nishati mbadala ni kuwa pamoja na kuzuia mabadiliko ya hali ya hewa, miradi hii inaweza kutoa nafasi nyingi za ajira vijijini na kwa hivyo kuchangia pakubwa kwa pato la taifa kwa jumla. Kulingana na utafiti, kuna uwezekano was miradi hii kuchangia 500 ej/kwa mwakani 2050, mchango mkubwa wa makusudio haya ukitoka nchi zinazoendelea.

Uzalishaji na utumizi wa nishati mbadala unaweza kuwa na faida mbali mbali za kijamii na kiuchumi katika nchi zinazoendelea. Baadhi ya faida hizi ni ongezeko la pato kwa wakulima, uongezeko wa nafasi za kazi vijijini na kuchagia katika kuimarisha hali ya maisha kwa wanachi husika. Hata hivyo, inaweza kuwa na madhara, kama vile ukataji miti na kudhuru viumbe hai katika mazingira. Pia, inaweza kuchangia kwa uhamishaji watu na mashindano ya ardhi kati ya upandaji nishati mbadala na kilimo. Ushindani huu unaweza kusababisha upungufu wa chakula. Vile vile, kuna uwezekano wa ukosefu wa haki katika usambazaji wa faida za miradi hii ya nishati mbadala.

Kwa hivyo, miradi hii ya nishati ya mimea yaweza kuwa na faida au madhara. Hivo basi, miradi hii inapaswa kupangwa na kutekelezwa kwa uangalifu mkuu wa kimazingara, kijamii na kiuchumi. Ina maana kuwa, maswala endelevu na viashiria vya kimazingara na kiwakati, sharti yashughulikiwe. Mengi hayajulikani kuhusu hali halisi ya ukuzaji na usindikaji wa nishati mbadala ambazo zinaweza kusababisha faida au athari. Ukuaji wa kibiashara na usindikaji ulimwenguni, umesababisha maswala haya kupata umuhimu zaidi.

Mbinu moja ya kuhakisha mbinu za kimaadili katika uzalishaji wa nishati ya mimea ni kuunda mifumo ya vyeti. Hata hivyo, mifumo hii ya vyeti haizingatii maswala ya kijamii na kiuchumi ambayo ni muhimu pia. Kuna ukosefu wa utafita wa athari chanyu au hasi ya kijamii ya nishati hizi za mimea. Sababu ya uhaba huu w utafiti, ni kwamba utafiti huu unahitaji rasilmali na ujuzi unaozidi kiwango cha nchi nyingi zinazoendelea. Mifumo ya ukulima, ukubwa wa ardhi ya ukulima na sheria za ardhi katika nchi zinazoendelea, unatafautiana vikubwa na nchi za magharibi; ilhali mifumo mingi ya ukulima inayotumiwa katika nchi zinazoendelea inaigwa kutoka nchi hizi za magharibi.

Utafiti huu unalenga kuchangia katika kuboresha uchambuzi wa athari za kijamii na kiuchumi ya nishati za mimea katika nchi zinazoendelea. Utafiti huu unalenga kuchambua hali halisi ya athari ya nishati mbadala kwa misingi ya mazingara yanayokuziwa nishati hizi, na mbinu na mofumo inayotumika katika miradi hii.

Utafiti huu ulilenga maswala yafuatayo;

I. Ni vigezo vipi muhimu zaidi kulingana na athari za kijamii na kiuchumi katika mifumo hii ya nishati mbadala kwenye nchi zinazoendelea?
II. Kuna umuhimu gani wa viashiria toafauti (kinyubani, kikanda na kilimwengu) vya athari hizi?
III. Ni zana zipi ambazo zinaweza kutumika kama vipimo vya athari za nishati mbadala kiuchumi na kijamii?

Maswala haya yamefafanuliwa katika sura ya 2 na ya 7 katika utafiti huu. Kila sura inachambua athari ya kimizangara na kiuchumi ya nishati hizi mbadala katika mazingara tofauti na vipimo tofauti vya kigeografia. Kuambatana na matokeo tofauti katika sura ya 2 hadi ya 7, majibu na mapendekezo yafuatayo yametolewa;

I

Mambo yafuatayo yana ushawishi mkubwa wa athari za kijamii na kiuchumi. Mtindo teule wa biashara (biashara ndogo au kubwa), miadi ya kampuni (uwajibikaji wa kijamii), kiwango cha maendeleo ya mkoa ambao miradi hii inatekelezwa, hali na mifumo ya uchumi (inachangia katika hatari ya mradi kutokamilika), kiwango cha ujuzi na teknolojia, uwekezaji, uwezo wa kuhudumia masoko husika, gharama za uajiri (yaani njia tofauti zilizopo za watu kujipatia riziki au ajira), soko lililochaguliwa kuuza bidhaa hizi (nje au ndani ya nchi au kote).

Utendaji wa kiuchumi wa nishati za mimea ni kigezo muhimu cha athari za kijamii na kiuchumi. Utendaji dhaifu wa kiuchumi, husababisha kudhoofika kwa miradi hii, huadhiri pato. Pia, huenda ukasababisha madhara ya kijamii na kiuchumi, kama vile, kupunguzwa kwa ardhi ya miradi hii, ukosefu wa chakula na uadhirikaji wa ustawi wa jamii.

Gharama muhimu katika mifumo ya kwanza ya nishati za mimea ni uzalishaji hiwa mimea hiyo, wala si ubadulishaji wa mimea kuwa nishati au usafirishaji wa nishati hizi. Katika mifumo ya pili ya nishati hizi, ubadilishaji wa mimea hii kuwa nishati ndio gharama kubwa zaidi, lakini mbinu za kupunguza gharama hizi zinatarajiwa katika siku za usoni. Gharama za uzalushaji wa mimea huambatana na usimamizi. Upandaji wa mihogo na mikaratusi Afrika mashariki kwa mfano, huonesha mazao haya yana faida kubwa kwa kipindi cha miaka 24 kwa mapembejeo ya kati, ikilinganishwa na mapembejeo ya chini. Hii inatofautiana kutoka hasi, hadi zaidi ya $1000/ha kwa mihogo (kwa kiwango mshahara wa dola mbili kwa siku), na kiwango cha mia kadhaa hadi $1200/ha kwa mikaratusi. Tofauti hizi zinaambatana na tofauti za mavuno.

Nishati majani kutoka mimea kama vile maharage ya soya, miwa au mitende, tayari zina fanya vizuri kibei zikilinganishwa na mafuta ya petroli (ukizingatia petroli ina gharama ya zaidi ya $100 kwa pipa) katika hali ya mazao ya juu na mbinu mwafaka. Kulingana na mazingira ya nchi, eneo, kiwango cha pembejeo na malighafi (na mavuno kulingana na vigezo hivi), gharama za uzalishaji nishati majani hutofautiana kutoka 5 hadi 45 US$/GJ.

Maharage ya soya, mitende, mikaratusi na poplar, ndio mimea malighafi yenye gharama ya chini zaidi kulingana na utafiti huu. Mafuta ya maharage soy (au kwa kimombo Soy straight Vegetable oil (SVO)). Mafuta ya mtende inaweza kuzalisha nishati majani kwa kiasi cha kati ya 10 hadi 15 US$/GJ kule Argentina kwa mbinu mbalimbali za ukulima. Mafuta ya mawese yanazalisha nishati majani kiasi cha 8 hadi 22 US$/GJ (kule Malaysia, Colombia, Indonesia), uzalishaji wa ethanol kotoka kwa mikaratusi kati ya 16 hadi 20 US$/GJ au 12 hadi 30 US$/GJ ukizingatia vigezo (kule Brazil na msumbiji), na nishati majani kutoka kwenye mmea wa poplar kule Ukraine 14 hadi 23 US$/GJ (ikipungua katika mwaka wa 2030 ukilinganishwa na 2020), lakini ukilzingatia vigezo zao la kati ya 12 hadi 42 US$/GJ.

Kule Indonesia, kuna mafanikio katika kupunguza gharama katika mashamba makubwa ya mafuta ya mitende, ikilinganishwa na mashamba madogo. Colombia inaweza kupunguza gharama za uzalishaji wa mafuta ya mitende na kumudu pato kufikia kiwango cha Malaysia (kwa gharama ya 8 US$/GJ), miradi mbinu ya uzalishaji ikiimarishwa. Ilhali mbinu za uzalishaji za karne ya pili hazina uhakika wa gharama za uzalishaji. Kama gharama hizi zinaweza kupunguzwa katika muda wa kati, Brazil na Msumbiji zina uwezo wa kuzalisha kati ya 12 hadi 16 US$/GJ.

Lazima kuwe na uwiyano kati ya athari za kiuchumi na kijamii. Mradi unaweza kuwa na matokeo bora kiuchumi, lakini kuathiri jamii kwa mfano, uhamishaji wa wakaaji wa eneo fulani au upungufu wa chakula wakulima wanapowacha kupanda chakula ili kukuza mimea ya nishati majani. Ilhali, mradi unaweza kuwa na matokeo bora kijamii, lakini kutofnikiwa kiuchumi. Kuna hatari kubwa ya mradi kama huu kotofanikiwa.

Athari nyingine ni ulipaji wa mishahara mikubwa kwa wanaozalisha nishati mbadala, unaoweza kusababisha bei ya juu ya nishati mbadala ikilinganishwa na petroli. Vile vile, ni muhimu kuzingatia miradi mingine ya maendeloe katika maeneo yanayo husika na ukuzaji wa nishati mbadala. Kwenye maeneo yenye nafasi chache, miradi ya nishati mdadala inaweza kuwa na faida za kijamii.

Kwa hivyo ni muhimu kuwa na malengo mwafaka, na kuchagua miradi ya nishati majani inayolingana na malengo haya yanayoipa kipaumbele miradi inayofanikisha malengo haya ya kijamii. Kwa njia hii, vigezo vinaweza kutatuliwa. Kwa mfano, ikiwa lengo ni maendeleo vijijini, uchangiaji mdogo wa kiuchumi wa nchi unakubalika, ikiwa miradi hii ya nishati majani inachangia lengo hili. Lakini ikiwa lengo ni kuokoa taifa fedha za kigeni, ni muhimu kuchagua miradi mikubwa ya nishati majani. Lazima kuwe na ujuzi mkubwa ili kufanikisha miradi mikubwa kama hii. Hato hivyo, malengo huenda yakabadilika kwa sababu tofauti; kama vile uimarikaji wa uchumi, uimarikaji wa mitindo ya ukulima au ufahamu mpya kutokana na utendaji.

II

Utafiti huu unaonyesha kuwa ni muhimu kutilia maanani athari tofauti za kiinchi, kimkoa, na kilimwengu. Athari za kilimwengu zinaweza athiri mifumo ya nishati za majani nyumbani. Vile vile, athari za kinyumbani zinauwezo wa kudhuru hali nishani majani ulimwenguni. Hata hivyo, mtindo huu mara nyingi hauthihiriki katika viashiria vya kiuchumi. Tofauti za kiuchumi na kijamii mikoani zinaweza kuwa kubwa, na hivyo kuathiri miradi ya nishani za majani.

Bei ya mafuta katika soko la ulimwengu huathiri utendaji wa kiuchumi wa miradi hii ya nishati za majani. Vigezo nchini kama vile kiwango cha misharaha ya wafanyikazi, utenda kazi na hali ya anga pia inaweza kuathiri miradi hii. Mazingara ya kisera na maendeleo ya kiuchumi katika eneo ambalo mradi unafanyika, unachangia katika upatikanaji wa ujuzi wa kazi. Katika maeneo yenye nafasi chache za kimaendeleo kama vile vijijini, mimea ya nishati za majani ambayo hayahitaji ujuzi mkubwa kama vile jetropha au mihogo, bado yanaweza kuimarasha mapato wa wanakijiji husika (mradi eneo hili halina upungufu was watenda kazi).

Ufanisi wa miradi ya nishati za majani ya karne ya pili unahitaji uzalishaji mkubwa na mbinu za kisasa za tekolojia. Mifumo kama hii haifai vijijini katika nchi zinazoendelea. Inafaa zaidi katika nchi zenye maendeleo kama vile Brazil, Argentina au Afrika kusini. Kwa hivyo ni muhimu kufanya utafiti kuhusu hali yakimaendeleo ya nchi, ili kuchagua mifumo mwafaka ya nishati za majani inayoifaa nchini husika.

Sekta tofauti za uzalishaji katika maeneo tofauti zianaathiri mifumo ya nishati za majani na athari hizi zinaweza kubainishwa kwa njia ya uchambuzi wa pembejeo na mazao. Miradi ya nishati za majani katika eneo moja inaweza kuimarisha sekta ya uzalishaji katika eneo lingine. Katika utafiti huu, athari za kikanda na mahusiano ya athara hizi yameonyeshwa wazi katika uchambuzi wa ethanol iliyo zalishwa kutoka kwa miwa kaskazini Brazil; ambao ulionyesha kuongezeka ufanisi na kutoa nafasi 30,000 za kazi mwakani 2020 na kuchangia zaidi ya dola bilioni moja. Mbali na hayo, kwingineko Brazil, kunauwezekano wa kupana nafasi zingine 14,000 za kazi na kuchangia zaidi ya dola robo bilioni. Haya yanachangiwa pakubwa na vifaa vya kisasa vya ukuzaji katika maeneo haya (yakilinganishwa na mwaka 2010).

Kuongezea, maeneo ya ukuzaji miwa kaskazini mashariki kunaweza kuchangia nafasi mpya za kazi takriban 200,000 kwa jumla Brazil. Hiki ni kiwango kikubwa kuliko matarajio ya upungufu wa nafasi za kazi kwa sababu ya utumizi mkubwa wa mashine. Mfano mwingine ni nchi zinazoendelea kutemea pakubwa mashine kutoka nchi za ngambo, hali ambayo inasababisha mathara kwenye uchumi wa nchi husika. Mahusiano haya ya athari hizi yameenea katika sehemu tofauti za kigeografia. Athari hizi zinasababishwa kwa kiasi fulan na hali ya kiuchumi ya nchi husika. Ni muhimu pia kuzingatia mazingara ya sera nchini husika.

Madhara nyumbani yanaweza kuathiri jamii mijini, ilhali miradi hii inaweza kutoa nafasi za ajira vijijini hata ingawa ajira hizi mara nyingi haziehesabiwi katika takwimu za kitaifa za uajiri. Tofauti za kitaifa za ukuzaji wa nishati za majani zanaonyesha wazi umuhimu wa kuzingatia mazingira ya eneo husiaka wakati wa kuchagua mifumo inayotumika. Uchambuzi mwafaka wa eneo husika ni sharti ukamilishwe, kabla ya uwekezaji wa miradi ya nishati za majani. Ni muhimo kulinganisha maeneo tofauti na mimea sawa inayokuzwa kwenye maeneo haya.

III

Uwezekano wa kiuchumi, athari kwa wanaohusika, hali ya utenda kazi, uwepo wa chakula, haki za kumiliki ardhi ni viashiria muhimu wakati uchambuzi wa athari za nishati za majani unapofanywa. Utafiti wa kitaifa unaweza kuathiri; kwa mfano hali ya utenda kazi, nafasi za ajira na kiwango cha mishahara. Mbali na hayo, viashiria tofauti kama vile masharti na viwango mwafaka ya utoaji wa vyeti yananaweza kupunguza idadi ya miradi isiyo kamilika. Vigezo vinavyotumika katika kutoa maamuzi ni muhimu yathihirishwe, ili kuchagia katika ukaguzi bora wa miradi hii na kuzipa nafasi mwafaka mbinu mpya. Haya yote hanapaswa kutekeleza kwa umakini, huku vigezo muhimo kama vile muda wa utendaji na gharama za uzalishaji zikitiliwa maanani.

Athari za kiuchumi katika jamii husika zinaweza kubainika, kwa kuchambua athari za nishati majani katika uajiri (uajiri wa mda na wa kudumu), uwekezaji wa makampuni katika maeneo husika(uwajibikaji wa kijamii), kiwango cha juu cha muda wa utendaji kazi, haki za wafanyikazi kukongamana, hali ya utenda kazi kama vile uwepo wa mavazi ya kinga (kwa wafanya kazi wote), mishahara ya watenda kazi.

Mbali na hayo, uwepo wa chakula unaweza kubainika kwa uchambuzi wa kiwango cha ardhi ya ukulima kilichobadilishwa ili kukuza nishati majani. Haki za umiliki wa ardhi zinaweza kubainishwa kwa kuchunguza kama kampuni za nishati za majani zinaumiliki wa vyeti hlisi visivyo na upinzani wowote. Ni ardhi ipi inayomilikiwa kijamii? Ni sehemu ipi ya ardhi iliyo na upinzani? Pia, ni muhimu kuchambua uwekezaji wa kampuni hizi kwa manufaa ya jamii kama vile hospitali, shule na kadhalika(uwajibikaji wa jamii).

Ni muhimu kuchambua athari tofauti na mahusiano ya vigezo tofauti, yaani vigezo vya kitaifa na jinsi vigezo hivi vinavyochangia hali ya kanda na dunia nzima kwa jumla; na kinyume chake. Kwa mfano, unaweza kuchambua uhusiano wa bei za soko la ulimwengu na zile za kikanda na kitaifa. Viashiri hivi vinaweza kutumika katika kubainisha ni mifumo ipi ya nishati za majani inayofaa, ukizingatia sera na mazingira ya kanda na chi husika.

Pamoja na hayo, viashari kama ustawi wa uchumi na idadi ya watu wasiokuwa na ajira, unaweza kutoa picha ya hali ya uchumi na maendeleo ya kanda au nchi ambayo mradi wa nishati za majani utakofanikishwa. Viashiria hivi vinaweza kusaidia kutambua vigezo muhimu kama vile uwepo wa chakula cha kutosha, haki za kike na mambo mengine muhimu ya kuzingatiwa. Mbali na uchunguzi huu wa juu, uchunguzi wa kina unastahili kufanywa ile kuelewa kwa undani eneo ambako mradi utatekelezwa. Kwa mfano, hali ya utenda kazi inasimamiwa kwa kina kule Argentina, lakini hali kule Tanzania ni tofauti. Ni wazo zuri kubainisha tofauti kati ya hali nchini na ile ya kimataifa.

Utafiti zaidi unapendekezwa kuchambua kwa kina;

- Athari za kimazingara na jisni athari hizi zinavyo changia athari za kijamii na kiuchumi
- Mahusiano ya maswala kama vile uwepo wa chakula cha kutosha, ushinda katika matumizi ya ardhi, maendeleo ya kanda; kwa mfano kwa kuunda mifumo mwafaka kama vile CGE-Models na viashiria bora vya maswala ya kijamii
- Kwa kulinganisha utozaju ushuru au ruzuku kati ya nchi tofauti wakati wa uchambuzi wa hesabu za utendaji wa kiuchumi.

Mapendekezo ya soko na sera;-

- Ni muhimu kutilia maanani na kuwa waangalifu wakati wa kuchagua mfumo ya nishati mbadala, kwa kuzingatia mazingara ya vijinini, nchini na kanda zima kwa jumla. Ni muhimu pia kuzingatia hali ya maendeleo ya kanda husika. Uamuzi utategemea hali ya eneo husika kiteknolojia, pamoja na ujuzi wa uzalishaji na kiwango cha maendeleo katika kanda husika. Uamuzi wa eneo mtakapotekelezwa mradi unapaswa kuzingatia hali ya hewa ya eneo hili, utumizi wa ardhi hivi sasa na hali ya kijamii na kiuchumi katika hili eneo. Vile vile, uwepo wa ujuzi wa kazi na uwepo wa miundombinu. Uchambuzi wa masuala ya kijamii na kiuchumi unapendekezwa kabla ya kutekeleza mradi. Umakini huu unaweza kuvumbua maswala nyeti. Kwa hivyo, hatua zifuatazo ni muhimu ilhali tathmini inkiendelea kila maswala mapya yakizinduliwa.
    1. Hakikisha kuna malengo wazi ya mradi wa nishati majani
    2. Amua eneo la utekelezaji
    3. Amua mfumo endelevu wa uzalishaji nishati hizi unaofaa na kiwango cha uzalishaji kinachostahili eneo husika.
    4. Chunguza kwa juu maeneo na maswala yenye utata
    5. Chunguza kwa kwa kina maeneo na maswala yenye utata (ukizingatia uchambuzi wa kitaifa na kanda zima)
    6. Chagua mfumo mwafaka wa uzalishaji nishani mbadala kasha tekeleza mfumo huu hatua kwa hatua
    7. Tathmini na ufuatilie utekelezaji wa mfuma na mradi huu kwa kina ili kuchukua hatua zifaazo kwa wakati mzuri.

  - Utekelezaji wa hatua kwa hatua utatoa nafasi nzuri ya kutathmini hali na kuchukua hatua zifaazo kwa minajili ya utekelezaji mwafaka ha hivyo kupunguza madhara ya kijamii na kiuchumi
  - Utafiti huu unaangazia kwa kina umuhimu wa maswala ya uendelevu kijamii na kiuchumi, katika mifumo ya uzalishaji nishati mbadala. Uundaji zaidi wa viashiria vipimavyo athari za kijamii unapendekezwa
  - Sekta ya Nishati mbadala ina uhusano wa karibu na sekta ya ukulima. Kwa hivyo ni muhimu sekta hii izingatiwe kwa vilivyo katika uundaji wa sera za ukulima. Kwa kufanya hivyo, athari za ubadilishaji wa ardhi za ukulima ili kuzalisha nishati mbadala zitapunguzwa na hivyo kuongeza ufanisi wa sekta hizi.
  - Utoaji wa vyeti unaweza kuhakikisha usimamizi bora wa sekta ya ukulima. Sera mwafaka, haswa zinaweza kutoa mashauri ya uendelevu katika sekta nzima ya kilimo kwa jumla. Kwa kufuatilia na kutathmini maswala ya kijamii na kiuchumi kama vile uwepo wa chakula cha kutosha (katika makakanda ya nchi zinazoendelea), kwa kutekeleza miradi ya majaribio na kuiimarisha na kuikuza kwa mda mrefu. Miradi ya majaribua hutoa fursa ya kujifunza maswala mwafaka na njia bora za kutekeleza miradi hii, na hivyo kuepuka athari zinazoweza kusababisha matokeo mabaya.
  - Ukosefu wa utafiti ni changamoto katika uchambuzi wa athari za kijamii na kiuchumi. Utafiti zaidi wa kitaifa na kikanda unahitajika. Kuna haja kubwa ya

ushiriano kati ya serikali, mashirika ya kimataifa na mashirika au makampuni binafsi ili kufanikisha utafiti zaidi. Mawazo ya msingi yanayotumika katika hesabu za kiuchumi yanapaswa kufafanuliwa. Baadhi ya maelezo yanayopaswa kutolewa ni takwimu za kijamii na kiuchumi (katika nchi na kanda zima) na ufafanuzi wa mbinu za tathmini unahitajika.

- Ugeuzi wa mimea kuwa nishati za majani unapaswa kutekelezwa kwenye nchi mnakokuzwa mimea hiyo, kwa kuwa kuna faida nyingi za kiuchumi kwa nchi hizi. Faidi hizi hutegemea kama kuna ununuzi wa mashine na technologia kutoka nje ya nchi. Masoko ya kitaifa na ya kimataifa ya nishati hizi yanaweza kukuzwa kwa pamoja. Kwa kufanya hivi, kuna faida za kiuchumi na za kiutekelezaji. Ulengaji wa soko moja mwanzoni unaweza kusababisha ustawi wa maskoko mengine. Kwa mfano, uzalishaji wa nishati ulengao masoko ya nje unaweza kukuza utumize wa nishati zizo hizo kwenye nchi husika.
- Ni muhimu kupunguza athari zinazo sababisha miradi hii kutofanikiwa. Kufanikisha miradi midogo, ni muhimu kutoa mafunzo ya utekelezaji kwa wanaohusika katika miradi hiyo. Kwa miradi mikubwa, ni muhimu kuhakikisha kuna uwekezaji na ujuzi wa kutosha. Pia, ni muhimu kuchambua na kuelewa kwa ndani maadili na tamaduni za eneo husika kabla ya kuwekeza miradi ya nishati mbadala, haswa katika nchi zinazoendelea.
- Ni muhimu kuzingatia utekelezaji wa hatua kwa hatua, ili kujifunza maswala mwafaka na hivyo kupata uzoefu. Vile vile, ni muhimu kufahamiana na kushirikiana ili kupata msaada wa nje. Faida za kiuchumi za miradi hii zinaweza kuimarishwa kwa kutumia mbinu za kisasa za teknologia na mifumo fanisi.
- Serikali zinapaswa kuhakikisha kuwa waekezaji wanamipango mwafaka ya maswala yote muhimu, ikiwamo mipago ya kuhakikisha wanapoondoka, wanaondoka kwa mpango ilu kuthibiti madhara ya kimazingara, kijamii na kiuchumi. Pia, serikali inapaswa kuhakikisha wanapoondoka wawekezaji, ardhi inarejea kwa wamiliki halisi.
- Mkoa haupaswi kulenga mmea mmoja tuu, ila unapaswa kulenga mimea, mbinu, masoko tofauti.

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Dankwoord

Dit proefschrift is natuurlijk niet tot stand gekomen door mij alleen, en daarom wil ik verschillende personen bedanken.

Allereerst mijn promotor André. Ons eerste contact was in Tanzania en ik ben blij met de kans die ik kreeg om te zorgen dat de artikelen die ik schreef in elk geval op degelijk veldwerk (al dan niet uit eerdere ervaringen) gebaseerd waren. Ik heb in verschillende, leuke internationale projecten mee kunnen draaien, en kon een maand in Londen verblijven. Dat heeft ervoor gezorgd dat ik het niet 'saai' ben gaan vinden. Je hebt me ook vaak zelfstandig laten handelen, bijvoorbeeld bij het projecten binnenhalen, of het managen van het UNEP of Global BioPact project. Dit was erg prettig, bedankt voor dit vertrouwen. Ook voor je enorm scherpe blik, die binnen no-time de essentie doorziet in een artikel.

Henny, je enthousiasme is enorm inspirerend, jij kunt je echt helemaal vastbijten in iets, en gelukkig ben je mijn copromotor geworden. Ik ben ontzettend blij met je, je scherpe geest en pen (in dit geval computer), hebben de meeste van mijn teksten een stuk efficiënter en duidelijker gemaakt. In moeilijke tijden kan ik altijd een beroep op je doen, dat is echt ongelooflijk fijn geweest! De artikelen komen steeds makkelijker van de grond. Ik denk nog wel eens terug aan de begintijd met Kees Daey Ouwens, wat zou hij dit leuk gevonden hebben.. Ik hoop dat we in de toekomst nog meer samen kunnen werken. Het is erg leuk om altijd op de hoogte gehouden te worden van het reilen en zeilen van Diligent, blijf dat vooral doen!

Vooral op het einde heb ik veel hulp gehad bij het afmaken van dit boekje. Floor en Birka, jullie hebben gelukkig nog goed meegekeken naar de Engelse samenvatting, bedankt daarvoor! Zonder jullie hulp had ik het op die dag niet gered. Carina, dank voor je hulp bij de Nederlandse samenvatting en natuurlijk voor de theetjes ;-), en Rosalien, voor het editing-check-werk, fijn! Mark Kamau, thanks for your excellent cover design! Poa sana! Hope you can see the printed result soon, here or in Nairobi. I know the Swahili translation took a lot of time, let's hope it helps to get the message out. Asanta Sanaaaa! Na karibu Utrecht.

I would like to thank all project partners from the Global Bio-Pact project, in particular Rainer and Dominik who provided excellent coordination. The trip together with Rocio in Mali with Mohito-cocktails on the roof of a mud-hotel was unforgettable! Rocio, thanks to you I was able to stay at Imperial College London for a month, which was a great experience. Thanks for that! I hope we can continue to work together and you are always welcome for a drink in Utrecht, or wherever around the world. Jorge, the (long!) fieldtrip in Argentina was great, and also the collaboration on the other research was very fruitful. Alison, and Ousmane, you made the trips in Indonesia and Mali very smooth. Thanks also to Abigail, Martijn, Nils, Estomih, Kate, Sébastien and Anne-Sophie, Arnaldo,

Pedro and Camilla, and all other partners and participants. The global Bio-Pact meetings were always like a little reunion, a pity that the project has ended!
I would also like to thank all project partners from the UNEP/UNID/FAO/GEF project. Bernd, Guido, Susanne, Uwe I enjoyed our joint efforts in this sometimes 'headache-providing' project. Also Jerome, Fatin and Emese, Diego, and our local partners, Tereza, Camilla, Tetiana, Olga, Jorge, Estella, Jose, Néstor and Felix Carlos, and all other project partners.

Een aantal projecten (en hoofdstukken) zijn mede tot stand gekomen met steun van RVO.nl, rijksdienst voor ondernemend Nederland (eerder Agentschap NL). Kees Kwant, via duurzaamheid bij de Tanzaniaanse overheid naar het Utrechtse.. Ik ben blij dat de onderzoeken naar Jatropha, en verschillende meetings mogelijk waren. Carmen Heinze, de samenwerking was erg prettig. Wie weet komen we elkaar bij Esperanzah tegen. Ook alle andere project partners, oa Frank de Ruijter, en Sven Sielhorst bedankt voor de samenwerking.

De studenten die ik begeleidt heb, hebben (soms indirect) ook een bijdrage geleverd aan dit proefschrift. Sarah Herreras Martinez, it was an enormous amount of work to collect the data in Brazil, and the model was complex, but you made it and the result is really excellent. Jouke Rom Colthoff, het werk in Mozambique was (zoals altijd daar helaas) niet altijd even gemakkelijk, maar je hebt je er goed doorheen geslagen en je werk is al in 2 papers verwerkt! Of course also Vasco Diogo and Merijn van Rossum, thanks for the work on Argentina.

Bert, jouw kennis van 'iemand die iets met nootjes doet' hebben ervoor gezorgd dat ik op het biofuel pad ben geraakt. Dit bleek, en is nog steeds, een erg interessante weg! Ruud van Eck, ook al was de insteek toen niet wetenschappelijk, het werk daar heeft me toch geholpen bij het tot stand brengen van dit boekje. And of course also a big asante sana to my former colleagues from Tanzania; Enil your cultural knowledge was indispensable, and of course also from Faustina, Adam and all others. Tutaonana!

Natuurlijk ook al mijn oud- en huidige collega's in Utrecht. Edward dank voor je hulp in het begin en voor het idee van het jatropha paper. Floor, als roomie hebben we al heel wat meegemaakt, van skiën in Wenen tot inderdaad het bouwen van een brug over een (niet bestaande) weg, in de regen, in de middle of nowhere in Mozambique. Het was super om met jou die trips te maken, en dank ook voor je ondersteuning met GIS en andere zaken. Hopelijk kunnen we nog eens een road trip maken ergens! Ook mijn andere collega's bedankt voor de inhoudelijke discussies en gezelligheid; Birka, Pita, Martin, Andrea, Carlina, Sanne, Rosalien, CS, Bothwell (so nice to discuss the 'crazy' things in Africa), Hans, Ric, Deger, Niels, Gertjan, Judith, Michiel, Marlinde, Sara, Bart, and all others.

Het secretariaat maakt het afhandelen van zaken net even wat handiger, sneller maar vooral ook gezelliger! Dank Siham en Petra daarvoor, en voor de hulp met het proefschrift zelf natuurlijk. Ook Aisha, enorm bedankt, ik heb me erg gesteund gevoeld, vooral tijdens de laatste tijd, erg fijn!

Katrien en Vivianne, ik had me geen betere paranimfen kunnen wensen! Jullie to-do lijstjes, die steeds langer werden, zijn uiteindelijk (bijna) allemaal afgevinkt. Het feest wordt vast heel gezellig, super dat jullie me door die laatste maanden heen geholpen hebben, ik had het echt nodig! Fijn dat ik altijd op jullie kan rekenen, ik hoop dat jullie weten dat dat andersom ook zo is.

Dan natuurlijk ook nog mijn vrienden en familie die, hoewel zij niet direct aan de inhoud van dit boekje hebben bijgedragen, er toch mede voor gezorgd hebben dat ik juist ook leuke dingen heb kunnen doen. Vieky, Marije, Sanne (Esperanzah!) en Raymond, Walter, Rob, Pieter, Marije (Ibiza!), dat was super! En Marieke, onze maandag-avondjes zijn op een gegeven moment legendarisch geworden. Marijke en Jelly, bedankt voor de etentjes en het aanbieden van woonruimte. Gerda&Oenze, het klusweekend was erg welkom! Ook voor de afleiding en leuke gesprekken, steun en alles waar je vrienden en familie voor hebt; Anne, Jasmijn, Stefanie, Fontessa, Diana (DJ..), Marije (je heerlijke kookkunsten), Claudia, onmogelijk om hier iedereen te benoemen. En zussie en Gertjan, als Suusje wat groter is, ga ik dit proefschrift in Jip-en-Janneke taal proberen uit te leggen… ☺ Last but not least… mijn ouders, dank voor jullie steun en de vrijheid die ik altijd gevoeld heb.

Dus voor iedereen hierboven en degene die ik niet specifiek genoemd heb: Bedankt, asante sana, gracias, obrigada, terima kasih, thanks!

Janske

Curriculum Vitae

Janske van Eijck was born on 19th of July 1980 in Tilburg, the Netherlands. She did a Bachelor at the Hogeschool Brabant; Environmentally oriented materials technology (Milieugerichte Materiaaltechnologie), and wrote her thesis in 2002 on biofuels in India for which she stayed for several months in Bangalore, India. After her Bachelor's, Janske continued studying at Eindhoven University of Technology to do the Master of Science 'Technology and Policy for Developing Economies'. She wrote her thesis on the jatropha biofuel sector in Tanzania which was awarded with the second prize in the Africa Thesis award and therefore published. Janske graduated with great appreciation in 2006. She was then appointed as manager of a Dutch Jatropha biofuel producing company in Tanzania, Diligent Tz ltd. She has lived in Tanzania for three years. Under her management this (then start-up) company in Tanzania grew from 3 to 30 employees, covering more areas and farmers in Tanzania, and the company obtained a lot of media attention, especially when the company fuelled the Air New Zealand test flight. After relocating to the Netherlands in 2009, Janske started working at the Copernicus Institute of Sustainable Development, Utrecht University, on the potentials and socio-economic and environmental impacts of bioenergy systems in developing countries. As a researcher, she worked on various international projects, coordinated and managed (parts of) these projects, and supervised MSc. students. The projects she worked on included the "Global Bio-pact Project", a project funded by the European Union 7th Framework Programme, the targeted research project "Global Assessments and Guidelines for Sustainable Liquid Biofuels" that was funded by UNIDO, FAO, UNEP and GEF, and on several projects funded by the Netherlands Enterprise Agency (RVO.nl), Solidaridad and Sasol. For these projects she coordinated local partners in different countries including Mozambique, Argentina, Costa Rica, Indonesia, Brazil, Ukraine and Mali, and collected field data including extensive fieldwork trips of several weeks to collect data in Mozambique. The results of most of these projects are presented in this thesis.

Scientific publications

Peer-reviewed articles

1. Diogo, V., F. v. d. Hilst, J. v. Eijck, J. A. Verstegen, J. Hilbert, S. Carballo, J. Volante and A. Faaij (in press). "Combining empirical and theory-based land use modelling approaches to asses economic potential for biofuel production avoiding iLUC: Argentina as a case study." Renewable and Sustainable Energy Reviews.
2. Van Eijck, J., H. Romijn, A. Balkema and A. Faaij (2014). "Global experience with jatropha cultivation for bioenergy: an assessment of socio-economic and environmental aspects." Renewable and Sustainable Energy Reviews **32**: 869-889.
3. Van Eijck, J., H. Romijn, E. Smeets, R. Bailis, M. Rooijakkers, N. Hooijkaas, P. Verweij and A. Faaij (2013). "Comparative analysis of key socio-economic and environmental impacts of smallholder and plantation based jatropha biofuel production systems in Tanzania." Biomass and Bioenergy **61**: 25-45.
4. Herreras Martínez, S., J. van Eijck, M. Pereira da Cunha, J. J. M. Guilhoto, A. Walter and A. Faaij (2013). "Analysis of socio-economic impacts of sustainable sugarcane-ethanol production by means of inter-regional Input-Output analysis: Demonstrated for Northeast Brazil." Renewable and Sustainable Energy Reviews **28**(0): 290-316.
5. Van Eijck, J., E. Smeets and A. Faaij (2012). "The economic performance of jatropha, cassava and Eucalyptus production systems for energy in an East African smallholder setting." GCB Bioenergy **4**(6): 828-845.
6. Van Eijck, J. and H. Romijn (2008). "Prospects for Jatropha biofuels in Tanzania: An analysis with Strategic Niche Management." Energy Policy **36**(1): 311-325.

Three more articles are forthcoming, see Chapter 4 and 7, and the third forthcoming article is ‘Economic and social sustainability performance of jatropha projects: Results from field surveys in Mozambique, Tanzania and Mali by, H. Romijn, B. de Jong and J. van Eijck.

Book chapters

1. Van Eijck, J. and A. P. C. Faaij (2014). Analysis of Socio-Economic Indicators on Different Bioenergy Case Studies. Socio-Economic Impacts of Bioenergy Production. D. Rutz and R. Janssen, Springer**:** 267-284.
2. Van Eijck, J., E. Smeets and A. Faaij (2012). Jatropha: A Promising Crop for Africa's Biofuel Production? Bioenergy for Sustainable Development in Africa. R. Janssen and D. Rutz, Springer Netherlands**:** 27-40.