Biofuels and the sustainability challenge:

A global assessment of sustainability issues, trends and policies for biofuels and related feedstocks

Biofuels and the sustainability challenge:

A global assessment of sustainability issues, trends and policies for biofuels and related feedstocks

By:

Aziz Elbehri
Anna Segerstedt
and
Pascal Liu

TRADE AND MARKETS DIVISION
FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
ROME, 2013

ISBN 978-92-5-107414-5

Preface

This report owes its genesis to the post food crisis of 2007-08, the ensuing debate over the impact of biofuels on global food security, and the rising concern over climate change and its close ties to sustainability. Moreover, the increasing debate over biofuel sustainability and the multiplicity of certification schemes that emerged over the last few years offered an opportunity for a global assessment with particular emphasis on trade, policy and food security.

The report underwent several drafts before reaching its final form. It started as a background literature review to a project proposal on biofuel sustainability aimed at empirically testing the proposed sustainability principles and criteria in specific country cases. Anna Segersted provided the initial literature review under the supervision of the Senior author, while Pascal Liu guided the literature search on certification schemes. Supplemental literature reviews were carried out by Saurav Barat and Gavilan Ignacio to fill in remaining gaps.

The end outcome, is a comprehensive study that attempted to integrate into a single report the major issues related to biofuel and related feedstock sustainability. The final draft was submitted for internal reviews and benefitted from comments from FAO colleagues from several departments including: Theodor Friedrich (FAO-AGP), Olivier Dubois (FAO-NRC), Kevin Fingerman (FAO-GBEP), and Merritt Cluff (FAO-EST). However, remaining errors are the sole responsibility of the authors.

The authors acknowledge the support of David Hallam, Director of the Trade and Markets Division. Patricia Arquero, provided the needed administrative support, Massimo Iafrate prepared the statistical production and trade tables while Marion Triquet assisted with final cross checking the document for consistency. The report formatting and design was ably carried out by Rita Ashton and Jane Garrioch.

Table of contents

List of boxes

List of figures

List of tables

List of acronyms and abbreviations

AFS	Australian Forestry Standard
AT	Alianca da Terra
BAFF	BioAlcohol Fuel Foundation (Sweden)
BNDES	Brazilian Development Bank
BQA	Biofuel Quota Act (Germany)
BSO	Biomass Sustainability Ordinance (Germany)
CBA	Cost Benefit Analysis
CCOF	California Certified Organic Farmers
CERFLOR	Brazilian Program on Forest Certification
CGEE	Center for Global Environmental Education
CHP	Combined Heat and Power
CIAT	Centro International de Agricultura Tropical (International Center for Tropical Agriculture)
CPR	Common Property Resources
CRP	Conservation Reserve Program (US)
CSBP	Council on Sustainable Biomass Production (US)
DDGS	Distilled Dried Grains with Solubles
DLUC	Direct Land Use Change
EEA	European Environmental Agency
EFA	Ecological Footprint Analysis
EIA	Environment Impact Assessment
EPA	Environment Protection Agency (US)
EPFL	Ecole Polytechnique Federale de Lausanne
ETS	Emissions Trading Schemes
EU	European Union
FAO	United Nations Food Agriculture Organization
FDI	Foreign Direct Investment
FLO	Fairtrade Labeling Organization
FSC	Forest Stewardship Council
GBEP	Global Bioenergy Partnership
GEXSI	Global Exchange for Social Investment
GGL	Green Gold Label
GHG	Green house gases
GSI	Global Subsidies Initiative
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IDB	Inter-American Development Bank
IEA	International Energy Agency
IFAD	International Fund for Agricultural Development
IFOAM	International Federation of Organic Agriculture Movements
IGCC	Integrated Gasification Combined Cycle
IICA	Instituto Interamericano de Cooperación para la Agricultura (Inter-American Institute for Cooperation on Agriculture)
IIED	International Institute for Environment and Development
ILO	International Labor Organization

ILUC	Indirect Land Use Change
IPCC	Intergovernmental Panel on Climate Change
ISCC	International Sustainability & Carbon Certification
ISEAL	International Social and Environmental Accreditation and Labeling
ISO	International Standards Organization
IUCN	International Union for the Conservation of Nature
IWMI	International Water Management Institute
LCA	Life Cycle Analysis
LCFS	Low Carbon Fuel Standard (California, US)
LEI	Lembaka Ekolabel Indonesia
LUC	Land Use Change
MPOB	Malaysian Palm Oil Board
MPOC	Malaysian Palm Oil Council
MTCC	Malaysian Timber Certification Council
NGO	Non-Governmental Organization
NPV	Net Present Value
ODP	Ozone Layer Depletion
OECD	Organization for Economic Co-operation and Development
PEFC	Program for the Endorsement of Forest Certification
R&D	Research and Development
RED	Renewable Energy Directive (EU)
RFS2	Renewable Fuel Standards 2 (US)
RSB	Roundtable on Sustainable Biofuels
RSPO	Roundtable on Sustainable Palm Oil
RTFC	Renewable Transport Fuel Certificate (UK)
RTRS	Roundtable on Responsible Soy
SAN	Sustainable Agriculture Network
SBA	Sustainable Biodiesel Alliance
SEA	Strategic Environmental Assessment
SFI	Sustainable Forest Initiative (North America)
SIA	Social Impact Assessment
SRWC	Short Rotation Woody Crops
UNCTAD	United Nations Conference on Trade and Development
UNDP	United Nations Development Programme
UNEP	United Nations Environment Program
UNICA	Brazilian Sugar cane Industry Association
US	United States
USDA	United States Department of Agriculture
WCED	World Commission on Environment and Development
WF	Water Footprint
WTO	World Trade Organization
WWF	World Wildlife Fund
ZAE Cana	Zoneamento Agroecológico da Cana-de-Açúcar (Sugar cane agro-ecological zoning) (Brazil)

Main conclusions

1. The initial surge of biofuels in industrial economies was driven by energy security and rising fossil fuel prices; but market forces alone were not sufficient to drive the process, which required heavy policy support (subsidies, mandates and tariffs for imports) targeting few domestic-based feedstocks (corn, rapeseed, soybeans); meanwhile research and development of new feedstocks to support future biofuel expansions took off, including high-yielding (sweet sorghum) and more versatile crops (jatropha), as well as dedicated energy crops for second-generation biofuels. Yet the expected large gap between future demand and potential domestic supply in the North required expanding biofuel production in developing countries, which had the land and the climate needed to produce raw feedstocks on a large scale.

2. However, rising concern about climate change and its necessary mitigation as well as the increasing awareness of the relationship between climate change and sustainability has altered views about biofuels, including a criticism of biofuels using feedstocks that are only moderately efficient but requiring direct subsidies. Moreover, the food crisis of 2007-08 and the debate over food-versus-fuel competition has raised concerns about biofuels clashing with food security and ushered in a critical debate about the long-term sustainability of current biofuel systems.

3. Measured in terms of efficiency and sustainability, feedstocks grown for biofuels are not alike. Crop feedstocks such as sugar cane or palm oil are relatively more efficient, in terms of biofuel yields per area, and can be economically viable without direct subsidies. However, their environmental sustainability comes into question when water irrigation is required (sugar cane) or when plantations take place in carbon-sensitive lands (palm oil). Sweet sorghum, still under development, offers high-efficiency potential and wider scope for adaptability to soil and water conditions compared to sugar cane. However, sweet sorghum quickly loses sugar after harvest, therefore limiting its adaptability to those countries with well developed infrastructure and supply chain capabilities.

4. Established feedstocks for ethanol (corn) and biodiesel (rapeseed, soybeans) have thrived largely under the protection of subsidies and mandates, but their long-term economic and environmental sustainability are not clear, and the future prospects of these first-generation biofuels will depend on a range of factors including the possible deployment of new and efficient feedstocks, the improved economics of biofuels through continued innovations, future policy support, as well as the commercial deployment of second-generation biofuels and related feedstocks, including waste, residues and other non-crop biomass.

5. Alternative feedstocks with potential growth in developing countries like jatropha and cassava may present attractive agronomic characteristics and good suitability in marginal lands with varying weather, water and soil conditions; yet several obstacles may limit the scope of these crops as future feedstocks. Key among these is the economic need to ensure intensive management systems to maximize yields and efficiency, which may lead to direct competition for prime land, often with established infrastructure and where food production is already established. In the end, the

economics of production will likely trump the agronomy of the crops. Hence the prospects of seeing widespread use of these crops as biofuel feedstocks are not optimistic, especially for poor, least-developed countries that may have idle land but limited value chain development capacity and the required infrastructure to support it.

6. Assuming second-generation biofuels become commercially viable, we can expect significant expansion of biomass use (broader set of crop feedstocks, waste and agricultural residues). Such development will likely alter the demand and supply of biomass sources, and hence their economics, tightening even more the agriculture-energy linkages, and the potentially even more intensive competition for land between food and energy uses. This in turn will have uncertain implications for rural development opportunities, especially in poor, developing countries that continue to rely heavily on traditional uses of biomass that are neither sustainable nor climate-smart. What is clear is that the economics of production will be the determining driver in sorting out how resources (land, labour, water and other resources) are likely to shift between food or energy. If the past is any guide, the market forces alone are unlikely to be the sole drivers of these processes, and the role of policy support (through incentives or disincentives) will also be critical in guiding the outcomes.

7. From a sustainability perspective, biofuels offer both advantages (energy security, GHG reductions, reduced air pollution) and risks (intensive use of resources, monocultures, reduced biodiversity, and even higher GHGs through land use change); and measuring biofuel sustainability requires approaching economic, environmental and social sustainability in an integrated way to maximize benefits and minimize risks. Yet the review of the biofuel sustainability initiatives taken as a whole does not show that such an integrated framework is being pursued or that the impacts of the core dimensions of sustainability are fully measured or understood.

8. Biofuel certification schemes, despite their multiplicity, are dominated by a singular form of governance – namely voluntary, private industry-led initiatives targeting sustainability assurances with input from non-industry stakeholders. These schemes are driven as much by market access and trade considerations as by the need to provide sustainability assurances. This may explain why the first schemes and initiatives have focused on those feedstocks and biofuels most involved in south-to-north trade (soybeans, sugarcane and oil palm). This dual role of biofuel certification schemes also explains the tendency to target selected sustainability criteria and not others and hence the absence of a full integration of the three core dimensions (economic, environmental and social) into a coherent framework or strategy.

9. National and supra-national initiatives on biofuel sustainability have been led by Western Europe – a region that is most dependent on future imports of biofuels and feedstocks to meet projected domestic needs. Leading exporting countries like Argentina, Brazil, Indonesia and Malaysia have also responded with their own sustainability initiatives in part to protect their export markets and to meet importing countries' requirements. Transnational forums, such as the Global Bioenergy Partnership, have been set up to harmonize sustainability initiatives across interested countries. Such forums emphasize consensus building around methodologies and other voluntary meta-standards, but they are unlikely to agree to fully harmonize policies or approaches (outside voluntary guidelines) that may clash with their national biofuel or renewable energy policies, driven by domestic priorities.

10. Competitiveness of biofuels in the long run will continue to depend on the economics of fossil energy, the policy support environment, and the relative incentives and disincentives to encourage renewable versus fossil-energy sources. Economic competitiveness of biofuels will also depend on the substitution possibilities between food and fuel market uses, and the advances in technology and innovation in biofuel production processes. Continued reliance on policy support through subsidies and mandates indicates the lack of market competitiveness of biofuels in the short and even the medium run.

11. A full assessment of economic biofuel sustainability require a complete internalizing of the full-cost of environmental effects (i.e. putting a market price on negative externalities). On the other hand, economic sustainability may clash with environmental considerations when the need to maximize returns on investments dictates pursuing intensive management practices that could clash with sustainable use of resources, and exacerbate competition with food for productive resources such as land. Consequently, large productivity gains are required to minimize such conflicts and bridge the gap between efficiency and long-run sustainability.

12. Environmental sustainability assessments for biofuels are difficult owing to the complexity and the multiplicity of indicators, some of which are global (GHG, renewable energy), while others are local or regional (water management, soil and resource depletion, local pollution, etc.). Initiatives on sustainability via regulations, directives or private-led certification schemes have had no clear and measurable impact, apart from increased awareness of their importance, and this despite the numerous initiatives and the huge sustainability debates. A key problem continues to be a lack of consensus on measurement methodologies (such as life-cycle analyses and the way to tackle indirect land use change). Moreover, certification schemes are of recent creation and continue to be impeded by inherent measurement and monitoring problems, which vary according to situation (location, feedstock, technology, alternative resource use, policy environment and local capacity). Until progress is made on these obstacles, the approaches pursued so far will continue to be selective and haphazard, focusing on self-selected sustainability measures and ad-hoc rules such as no-go zones for high-carbon stock or biodiversity-rich areas.

13. The social impacts of biofuels certification schemes remain the weakest link in most sustainability initiative thus far. Most certification schemes, scorecards and regulations make mention of social impacts but only seek to mitigate few of the obvious negative impacts (child labour, minimum wage, compensation for lost land and resources) or call for adherence to national laws or international conventions. However, evidence of how these measures are actually implemented, or their impacts on the ground, has been very limited, and successful cases are rare. Among the reasons are the complexity of social impacts, and their inherently local context, often encompassing contrasting social norms, practices, capacity, community empowerment and varied levels of political participation. Clearly, the social sustainability dimension requires a qualitative rethink that goes beyond mitigating few negative impacts, but rather integrates participatory processes that ensure wider economic benefits to marginal stakeholders and local communities, and therefore guarantees broader acceptance and long-lasting stewardship of resources.

14. From food security and rural employment perspectives, biofuel certification schemes, unless tied to specific public initiatives, are not structured to be inclusive of small-scale producers. Most certifications require costly, complex and intensive information systems and management capacities that are easily absorbed by large-scale agribusinesses (with their advantage of economies of scale) but are largely out of reach for small-scale producers. This implies that private-led certification schemes may not be sufficient by themselves to facilitate wider participation in promising feedstock-biofuel value chains or to offer small-scale producers opportunities for market diversification. Consequently, biofuel projects may have limited development, rural employment, and income-enhancing potential at a local or regional level. Filling the inclusiveness gap for small-scale producers, especially in poor, developing countries, requires active public interventions carefully tailored towards incentives to develop capacity, better organization, adoption of cost-cutting technologies and new techniques to enable smallholders to better leverage the new market opportunities offered by any new possibilities for biofuel-led agricultural value addition and diversification.

15. Linking biofuels to food security in developing countries also requires establishing closer links between food security and energy security. This requires choosing among different development model paths, depending on the stage of industrial development of the country, the general state of food security, the extent of agro-industry development and the capacities of producers and agribusinesses. No single model fits all situations. For poor countries with limited industrial capacity, emphasis should be placed on small-scale bioenergy systems that can integrate existing crop and livestock enterprises at farm, household and community levels. Such schemes have larger developmental benefit potential in terms of local employment, productivity enhancement and improved food security. FDI-induced larger-scale biofuel projects, on the other hand, may be suitable in those situations where countries have sufficient industrial capacity, besides land and biomass potential, and when these biofuel projects can be fully integrated into domestic energy strategies that do not conflict with food production potential and food security.

Executive summary

The development of biofuels, which has emerged at the interface of agriculture and energy at the global level, has been one of the most significant agricultural developments in recent years. During the 1990s, the industrialized economies of North America and Europe actively pursued policies in support of domestic biofuel industries to achieve energy security, develop a substitute for fossil fuels and support rural economies. In addition, the rising concern over climate change in the last decade propelled interest in biofuels as a possible means of mitigating greenhouse gas (GHG) emissions.

The need to address the growing challenge of climate change has led to closer scrutiny of biofuels to assess whether they can be produced, traded and used sustainably. Criticism of biofuels centred around their perceived negative impacts on the environment through deforestation, spread of monocultures, loss of biodiversity and possible higher GHG emissions under uncontrolled land-use change. Moreover, the food crisis of 2007-08 and the ensuing surge of commodity prices heightened the debate over food versus fuel and the possible consequences of biofuel production on food security. The potential of biofuels to contribute to a shift into more sustainable energy systems became contested, and scientists started to question the environmental superiority of biofuels.

As a result of these concerns, sustainability has been promoted as essential condition for biofuels long-term viability and for continued public support to renewable energy and to climate change mitigation. Consequently, a range of biofuel certification schemes emerged, all purporting to ensure sustainability. Yet these schemes also seem to be driven by the need to regulate the current and potentially huge future trade flows in feedstocks and biofuels between industrialized economies (with high potential excess demand for energy) and developing countries (with recognized comparative advantages in biomass production and huge potential excess supply).

What this report is about

This report addresses the central issue of biofuel sustainability using a global assessment of major commodities and feedstocks currently employed for bioethanol and biodiesel production. The approach taken was guided by two overriding considerations. First, the need to understand the basic dimensions of sustainability for biofuels (economic, environmental and social), their linkages and how they relate to the central challenges they address, namely land-use change, food security and climate change. Second, the need to critically evaluate the extent to which the recent trends in biofuel certification schemes reflect true sustainability versus trade flow regulation under the guise of sustainability; in other words, are the initiatives essentially market driven or sustainability motivated, or both?

The report is global in scope and surveys a large number of country case studies aimed at shedding light on the sustainability issues examined. It focuses on current biofuel production systems as well as the major biofuel sustainability initiatives and certification schemes.

The report is divided into three chapters. The first chapter provides a broad economic overview of the major feedstocks used to produce liquid, solid and gaseous biofuels. An analysis of each feedstock is presented, including a general overview of its production, energy and other input requirements, productivity and efficiency of biofuel generation. Chapter 1 also includes a review of country case studies focusing on a key biomass-biofuel pair to provide specific context to biofuels. Chapter 2 addresses sustainability as such, with a comprehensive review of the three core dimensions (economic, environmental and social). Chapter 2 also review country and inter-government sustainability initiatives relative to biofuels and bioenergy and serves as a sagueway to chapter 3. The latter provides a broad and critical review of the biofuel certification schemes.

Biofuel feedstocks: assessing sustainability beyond efficiency

In countries where biofuel industry is established, the first feedstocks utilised tend to be drawn from among the most important crops in the country (e.g. corn in the USA, rapeseed in the EU, sugar cane in Brazil and oil palm in Malaysia/Indonesia). Biofuels tend to be led by few dominant crops targeted through an active policy support program that also account for domestic biofuel consumption patterns (e.g. ethanol in the USA and Brazil and biodiesel in the EU). Still, to meet expanding future demand in biofuels, there is growing interest in exploring other possible feedstocks (e.g. sugar cane, cassava, palm oil, sweet sorghum, Jatropha) and dedicated energy crops (e.g. switchgrass, miscanthus and short rotation tree crops) for advanced ("cellulosic") biofuels. In this report, for ease of exposition, we divide the biofuel feedstocks into 4 broad categories: (1) high-efficiency feedstocks (e.g. palm oil, sugar cane); (2) moderate-efficiency feedstocks (e.g. corn, soybean, rapeseed, sugar beet); (3) feedstocks under development (e.g. sweet sorghum, Jatropha); and (4) dedicated energy feedstocks (e.g. switchgrass, miscanthus, short rotation crops, algae, waste).

Efficient feedstocks: not always sustainable

Sugar cane is an efficient crop (in terms of yield per unit of land), but its sustainability hinges largely on water availability and the crop does better when there is ample rainfall and minimal need for irrigation (as in Brazil). Besides high biomass, sugar cane also produces a range of useful by-products all contributing positively to its economic competitiveness. Sugar cane continue to be attractive even under second generation technologies as bagasse can be a prime feedstock source. Sugar cane also offers the possibility of using molasses (i.e. sugar production by-products) for biofuel in situations where sugar production has priority over biofuels (as in India). Sugar cane is also very demanding agronomically, requiring deep soils, high water use, and a full 12-month growing season; hence, sugar cane is less optimal in drier areas that require irrigation, especially if it has to compete with food crops for water use. Irrigated sugar cane is less of an option if water is sourced from depletable underwater or aquifers.

Another key concern with sugar cane with respect to sustainability is the potential undesirable impacts in terms of land use change. This has been a particular issue in Brazil, the world's leader in sugar cane ethanol, where sugar cane expansion into grazing areas, can push livestock systems into the forest zones. Brazil, being sensitive to these concerns, has placed restrictions on sugar cane expansion areas to minimize the negative impacts.

Next to sugar cane, **palm oil** is by far the most efficient source for biodiesel (yield per unit of land), far exceeding alternatives like rapeseed, soybeans or sunflowers. The bulk of world palm oil production is concentrated in Malaysia and Indonesia, but major investments in new plantations are also taking place in Africa and Latin America, driven by rising consumer demand, high potential for expanded trade and opportunities for biodiesel production. In terms of environmental sustainability, oil palm presents a huge dilemma. On the one hand, this oil crop is highly efficient and its GHG emission potential and energy balance compares favorably with alternative feedstocks. However, oil palm plantations can also pose environmental problems when expansion takes place on sensitive lands (e.g. peat soils, forests). This is a particular concern in Malaysia and Indonesia where some oil palm is planted in drained peatlands, resulting in significant CO2 emissions outweighing any carbon benefits arising from the new palm-oil plantations. A complicating factor is that new investments in new palm oil plantations are not only driven by biodiesel alone, but rather (or more so) by increasing consumer demand in vegetable oil in many high growth and populous developing countries. This in turn may minimize the impact of sustainability safeguards geared toward plantations focusing on biodiesel and not the underlying feedstock food crop.

Moderately efficient feedstocks, but no assured economic viability

Much of the burst in biofuel production in the USA and the EU depended on a few feedstocks that are only moderately efficient relative to alternatives. In the USA, maize is the predominant feedstock for ethanol, while rapeseed dominates biodiesel production in the EU. Maize has the advantage of high productivity per unit of land, although it also uses large amounts of fertilizers and pesticides, and hence consumes a lot of fossil energy. However, the increasing concern about climate change and GHG mitigation lessens the appeal of maize compared with sugar cane because its energy input-output balance, or carbon footprint, under current biofuel technology is relatively modest. In Canada and Europe, maize is traditionally used for feed, while in other countries (apart from china), white maize for food consumption pre-dominates. Therefore, maize has not been favoured outside of the US as an ethanol feedstock because of concerns about competition with food.

The EU, on the other hand, centred its initial biodiesel development strategy around rapeseed – a domestically grown crop that can be promoted through subsidies. This strategy squared fully with the overriding objective of achieving energy security through the promotion of renewable energy, including biofuels. Although more rapeseed is grown in Canada, China and India, only the EU (and to a lesser extent, Canada) has vigorously promoted rapeseed-biodiesel production, largely through heavy subsidies and mandates. However, in terms of biodiesel yield per acre or GHG savings, rapeseed feedstock doesn't compare favourably with other alternatives (such as palm oil). Consequently, there is very little biodiesel production from rapeseed outside of the EU's direct support. Even within the EU, there has been some retreat from direct support to rapeseed-biodiesel due to increased pressures on environmental grounds, seeing that rapeseed offers weaker benefits in terms of climate-change mitigation.

Soybean oil is the second-largest biodiesel feedstock after rapeseed oil. Biodiesel production from soy oil is concentrated in the USA and Latin America (e.g. Argentina, Brazil, Paraguay). China, a major soybean producer, does not produce biodiesel from this feedstock because of its ban on using food crops for biofuels and the fact that China is a net importer of soybeans. The largest expected expansion of soy oil for biodiesel is in Argentina and Brazil because of the availability of land and relatively lower cost of production. However, soybeans in these countries, under the current market forces, tend to be grown under monoculture systems which pose sustainability challenges. Moreover, expansion of corn for ethanol in the USA – which tends to reduce soybean acreage as corn-soybean rotation contracts –

pushes up soybean acreage expansion in Latin America. This, in turn, raises concerns over potential undesirable land expansion and even encroachment into forested areas, with potentially negative environmental and GHG emission consequences.

Promising feedstocks choice set: advantages and limits of new feedstocks

The prospects of even greater expansion of biofuels in the future unleashed a search for alternative and highly productive feedstocks to meet future demand. Among these, **sweet sorghum** has been the object of sustained research and development programmes in China, India and the USA. Sweet sorghum is the closest competitor to sugar cane in terms of yield potential per unit of land. Sweet sorghum is an annual crop that is more versatile and can be grown in a variety of soil depths and water conditions. Sorghum is drought-tolerant and can be grown in a shorter season with less labour requirements and is suitable in tropical areas too dry to grow sugar cane.

The drawback to sweet sorghum is that it requires quick processing after harvest because its sugar content drops significantly after only three weeks. This presents a challenge for transportation and storage given the bulkiness of the crop (i.e. 70 percent water at harvest).This may limit the number of countries capable of developing the industrial infrastructure to produce, harvest, store and process this bulky crop on a large scale. It further would lead to the need to concentrate production around the processing facilities limiting the options for more sustainable diversified production on that land (crop rotations). Another sustainability problem is the potential competition for food over land. A study on sweet sorghum in Mozambique showed that one solution to food competition is to plant sweet sorghum on fallow sugar cane land to be harvested and processed before the start of the sugar cane harvesting season. As a biomass source, under this system, the sweet sorghum fibrous residues can be used in the same way as sugar cane bagasse to produce electricity, process heat and power.

Another potential alternative feedstock for biodiesel is the non-edible crop, Jatropha. Jatropha is drought-tolerant, has low input requirements and is highly suitable for marginal lands. Jatropha can also improve the soil quality because of its deep root system; however, clearing Jatropha land for conversion into crop land would be a considerable investment. Equally important is Jatropha's suitability for small-scale production as its seeds can be easily stored before processing. However, large-scale biodiesel production is capital-intensive and thus requires tight supply arrangements such as out-grower schemes, in which producers deliver directly to local processing plants to ensure economic viability. India has been particularly keen on developing Jatropha for biodiesel in line with its non-food biofuel policy. Jatropha has also been tried in a few African countries (e.g. Ethiopia, Ghana, Mozambique). Still, the long-run economic viability of Jatropha for biodiesel is still untested. The key concern is that to ensure economic profitability, Jatropha would require intensive crop management which, in turn, would result in competition for top farm land unless explicit regulations on farm land use are in place. Consequently, the development of these feedstocks in more marginal areas by small-scale farmers is less likely without government incentives. In general any feedstock will compete with food crops for land and water resources. In other words, economics will trump agronomy in terms of where the feedstocks can be grown.

Cassava has also been targeted as a potential feedstock for ethanol because of its high starch content and high yield potential per hectare. However, cassava is a staple food crop in much of Africa and Asia and a critical food security source for many poor rural communities. This raises concern over its suitability as a biofuel feedstock, as the crop is for the most part grown by small scale farmers for self-consumption. Moreover, Cassava is a highly perishable crop and cassava value chains, especially in Africa, are typically impeded by limited processing technologies and underdeveloped marketing channels. Given the agronomy of the crop, its central role for food security among the poor and rural households in many parts of Africa, and the largely underdeveloped Cassava supply chains, there are serious doubts that such crop can become a magnet for biofuel development at the local level, at least not on a large scale or when involving a significant share of small farmers.

Feedstocks for second-generation biofuels: still facing unfavourable economics

Advanced biofuels (including "cellulosic" ethanol) are still under development and have yet to reach commercial stage. Dedicated energy crops (e.g. alfalfa, switchgrass, miscanthus), fast-growing short-rotation trees (e.g. poplar, willows, eucalyptus) and agricultural and wood residues offer much greater potential for the biofuel industry. But the economics and high capital investments for the new supply chains remain serious obstacles for 2nd generation biofuels.

Assuming commercialization stage has been reached, concern over land-use competition between food and fuel may not disappear simply because we can use agricultural residues or waste for feedstocks. The answer will turn essentially around economics and will depend on the relative costs of land-using feedstocks (e.g. dedicated energy crops) or non-land-using feedstocks (e.g. wood, municipal or other wastes). Even when agricultural residues (e.g. cereal straws) are targeted this would alter the economics of traditional crops (i.e. pushing up their market value) and would increase competition for land and not lower it. Moreover, the advent of the second-generation biofuels would create huge pressure for land to produce dedicated energy crops, hence worsening competition with food crops. The net effect on land competition will depend on whether the expansionary effect (resulting from a surge of investments in second-generation plants and the resulting high demands for feedstock) will dominate the substitution effect (i.e. away from traditional feedstock crops and into residues and waste). At any rate, second-generation biofuels, should they become commercially viable, would likely induce a fundamental shift in agricultural systems, and would bring much closer agriculture and energy markets, with far reaching consequences difficult to fully ascertain contemplate at this stage.

Biofuels and the sustainability challenge: framing the problem

The sustainability concept is complex and multidimensional, and its implementation on the ground requires an understanding of the specific local context. A sustainable biofuel production system is one that is economically viable, conserves the natural resource base and ensures social well-being. Moreover, the three core dimensions of sustainability (i.e. economic, environmental and social) are interlinked and can best be approached holistically.

From a sustainability perspective, biofuels offer advantages as well as risks. On the upside, biofuels can contribute to increased energy security, help reduce GHG emissions, improve air quality in cities and, in the process, spur growth in rural areas. On the downside, expansion of biofuels, especially under intensive production systems, could have negative impacts on biodiversity (e.g. replacement of natural forest with biofuel crops, spread of monocultures), water availability under scarcity, water quality, soil degradation, negative carbon and energy balances, potential conflict with food production and food security, as well as worsening GHG emission levels because of indirect land-use change.

Balancing the economic benefits with environmental and social impacts is a delicate act. Even when biofuels meet some environmental and social sustainability criteria, they need to first pass the economic sustainability (or viability) test. This means ensuring efficiency of production (through high yields and intensive management) and long run profitability, access to productive resources (e.g. land, labour, technology), and reliable output markets. The challenge is achieving all this while ensuring economic viability and minimizing potential negative social or environmental impacts.

Most of the initiatives on biofuel sustainability at the country or supra-national levels come from industrialized economies where biofuel growth has been most dynamic and where there is large scope for bioenergy demand and huge energy substitution possibilities. Sustainability initiatives coming from Europe or North America largely mirror the industrial economies' priorities for biofuels (e.g. energy security supply, protection of agriculture, and increasingly climate-change mitigation).

Because the EU (more than North America) depends relatively more on imported feedstocks for its biofuel needs, it took the lead in setting regulations and encouraging private-led schemes targeting biofuel sustainability. By contrast, the US's biofuel production being largely domestically-oriented, there is no comparable push to require broad based sustainability criteria for biofuels, apart from the requirement to regulate GHG emissions as required by existing legislation and Supreme Court rulings. Outside Europe and North America, major feedstock exporters (such as Argentina, Brazil, Indonesia and Malaysia) have responded to rising sustainability concerns, largely to protect their export markets. The other large developing economies, such as China and India, with huge populations to feed, have adopted a more cautionary strategy with biofuels avoiding altogether any feedstock that could be used as food or feed.

Are biofuel certification schemes enough to assure sustainability?

A number of sustainability initiatives defined through standards, principals and criteria as a regulating instrument for biofuel and feedstock trade. These initiatives, both national and transnational paved the way for several biofuel-specific certification schemes either targeting all biofuels as a whole or tailored to specific biofuel feedstocks (sugarcane, soybeans, palm oil etc). Despite their diversity, most biofuel certification schemes followed a dominant type of governance: voluntary, industry-led, multi-stakeholder forum with some input from civil society. It has advantages and disadvantages. On the upside, it allows the biofuel industry to self-regulate, while preserving market efficiency. Specifically, these private-led certification schemes have the ability to: (1) influence corporate social responsibility in biofuels; (2) influence businesses to improve efficiency within a supply chain; (3) decrease risk; and (4) raise awareness about problems in the supply chain. Also, the multiple forms of certification schemes (e.g. roundtables, consortia, private labels, industry-wide certificates) could generate positive pro-competitive effects, improving implementation and verification tools. On the other hand, a commonly raised concern among exporting countries is that certification schemes are viewed as disguised trade barriers. Another limitation of the voluntary-private based certification schemes is that sustainability itself may take second place to efficiency, especially if some provision of public goods is required through a direct public intervention.

Economic sustainability, subsidies, and competition with food and other feedstock uses

Economic sustainability (viability) requires long-term profitability, minimal competition with food production and competitiveness with fossil fuels. The economics of biofuels have been in part driven by active policy support measures (subsidies and mandates) which makes it difficult to assess the long run economic viability of biofuels systems current or future. However, the protection of the domestic biofuel industry (sugar-cane ethanol in Brazil from the 1970's, US corn-ethanol and EU rapeseed –biodiesel), have managed to develop the economies of scale and cut long run costs through the introduction of technological improvements (diversification and market opportunities for by-products; efficient internal energy consumption..etc).

The food crisis of 2007/08 triggered the food-versus-fuel debate and raised concerns about out-of-control expansion of biofuels to meet ever larger energy needs. If left unchecked, biofuel expansion could well shift food production into more marginal lands, resulting in lower yields. Also, competition over resources such as water and fertilizers may also constrain food availability (depending on feedstock and location). Competition could also enhance yields as a result of higher rents (i.e. the market price of land) and the adoption of other productivity boosting technologies (rotations, inter mixed-cropping). First-generation biofuels are also experiencing slow and progressive technological advances, including improved energy input-output ratios and increased market value and uses for by-products. However, these effects may vary depending on local market conditions and relevant policies or regulations in place.

Increased demand from biofuels for feedstocks tends to push up agricultural commodity prices, and trade is a key determinant in globalising biofuel market. However, if trade barriers are lowered (including tariffs) and biofuels are more openly traded, market competition would moderate prices. Further, higher commodity prices, by making food more expensive would draw resources from biofuels back into food production – a result of food-fuel competition over shared productive resources. The linkages between food and energy will likely grow stronger affecting the relative competitiveness of biofuels, and their long term viability and sustainability. This is especially the case should second generation biofuels become commercially available. In that case, competition for shared resources will become even more intense, and it is unlikely that policies or regulations would not have to step in to balance between food versus energy security.

Biofuels are bulk commodities with little scope for price premium. Moreover, the quasi-mandatory requirements for certified biofuels (or biomass) entering the EU market also remove the conditions for price premiums. Yet despite the added certification costs, many producers in developing countries are still able to compete in the European market as they can produce feedstocks more efficiently (at least the high yielding ones such as sugar cane and oil palm). This partly explain the much concentrated focus of certification schemes on few key traded biofuels feedstocks (sugar cane, oil palm, soybeans). By contrast, commodities produced, transformed and used domestically can fall largely outside the writ of these voluntary certifications schemes, especially in the absence of strong and enforced domestic regulations (e.g. corn-ethanol in the USA, sugar cane-ethanol produced and used in Brazil, soybean-biodiesel in Argentina, sugar in India, palm oil in Indonesia and beef in Brazil).

One complicating factor in assessing the economic sustainability of biofuels is the multiple market outlets for feedstocks (e.g. food, feed, fibre and, now, fuel). Yet, sustainability requirements as articulated in current certification schemes appear to be limited to biofuels use only. A certification scheme established on the basis of a single final use (i.e. biofuel) may be ineffective in securing sustainability, resulting in indirect displacement effects. One remedy is to focus on sustainability at the biomass production side. However, the substitution possibilities among different final-end uses of feedstock makes it difficult to enforce sustainability compliance if tied only to biofuel supply chains.

Environmental sustainability: multiple indicators and the challenge of measuring impacts

Environmental sustainability encompasses a broad set of issues, some are global (e.g. climate change, GHG mitigation, renewable energy), while others are more location-specific (e.g. water management, soil quality, erosion, water and local air pollution).

Environmental sustainability of biofuels has been largely defined in terms of reducing GHG (e.g. CO2, methane, N2O) emissions. For non- CO2 GHGs, agricultural practices ((e.g. soil tillage, irrigation practices, fertilizer use, pesticides, harvesting) are leading sources of emissions. Moreover, land use prior to biofuel conversion is also a critical factor in evaluating the environmental impact. A biofuels GHG reduction potential suffers markedly if grasslands or forests are used for biofuels.

Definitive assessments of the GHG effects of biofuels continue to be hampered by a lack of reliable methodologies to measure indirect land-use change, soil carbon, etc. Life-cycle analyses are increasingly used to measure the sustainability of various biomass-biofuel systems, but the methodologies so far are not standardized and have yet to adequately account for indirect land-use change.

Another important motivation for biofuel is the promise of energy substitution to replace fossil fuels. Energy balance (i.e. the ratio between renewable energy output and fossil energy input) show great variation among different biofuel feedstocks, with palm oil for biodiesel leading the pack with an energy balance up to 9.0 (i.e. nine times the energy required for its production). Sugar cane also has a relatively high but variable energy balance, ranging from 2.0 to 8.0. Most other feedstocks have energy balances that range from 1 to 4. Still, these calculations do not take into account the effect of indirect land-use change.

Besides GHGs and energy, water resource preservation may top other considerations in specific areas when evaluating environmental sustainability. In some cases, constraints regarding the quantity of water used and the impact on local water quality and future availability may be the most limiting factor against biofuels. Linked to water is the problem of fertilizer runoff– especially near streams and rivers.

Preserving biodiversity or avoiding biodiversity loss from biofuels is another critical criterion for sustainability. However, there are no standard ways to measure which systems to promote, except in general terms (such as use of rotations). Most current production systems do not indicate stability or even maintenance of biodiversity. Biomass production under intensive monoculture systems can have negative impacts on biodiversity including habitat loss, the expansion of invasive species and contamination from fertilizers and herbicides. However, the deployment of biomass in previously degraded land may benefit biodiversity; but this can only occur if there are strong enough incentives (including payments for environment services).

A general problem with the environmental side of certification schemes is the difficulty of translating principles and criteria into effective sustainability indicators on the ground. This is partly due to inherent problems with identifying measurable, permanent impacts of certification schemes. Another reason is the lack of available and meaningful data that enable proper comparison and assessment of compliance. Moreover, the principles and criteria themselves can be too broadly stated (with few exceptions) or, inversely, translated into indicators that are too narrowly specified, making it difficult to agree on broad values of sustainability. For example , the certification under the Round Table on Responsible Soy good agricultural practices such as crop rotations or zero tillage are not mandatory as they would reduce the market for soya qualifying under this certification.

Social sustainability: the weak link and inadequacy of current certification schemes

The social impacts of certification schemes are even less well documented. The key difficulty lies in the ability to translate social sustainability standards and criteria into measurable indicators. This is in part due to the wide range of social conditions, practices and norms (e.g. labour structures, types of land ownership, local resource management). Another reason is the highly location-specific context of social impacts. For example, the indicator "all workers receive minimum wages" may mean little in countries where informal employment is widely practised, particularly in the agricultural sector. If no formal contracts exist, compliance with this indicator might be difficult and costly to assess.

While the enactment of certification schemes may have some positive impacts on workers and local communities, there is still limited evidence of direct poverty-related impacts, improved food security, or enhanced sustainable income opportunities through value addition, expanded market opportunities and diversification. For most certification schemes and scorecards, the social aspects of sustainability are addressed only in terms of removing selected negative impacts (e,g. child labour, minimum wages), or calling for adherence to national laws or international conventions. However, critical social factors – such as participatory processes, common management of resources, health implications and other aspects of poverty reduction or smallholder inclusiveness – are not typically addressed as primary concerns of existing certification schemes. This may seriously limit the scope of these schemes as designed in addressing social sustainability in an integrated way.

In the end the existing biofuel certification schemes are not properly structured to adequately address social sustainability. The private-led "voluntary" schemes are not the correct instrument to address social issues that are essentially public good types. Rather the appropriate sustainability measures require strong national supplemental policies and regulations that safeguard the potentially broad domestic social benefits as part of any biofuel development. More than the economic and environmental dimensions, social sustainability for biofuels and related feedstocks need a serious rethink of how to mainstream and implement sustainability. Essentially we need to move away from simply focusing on targeting selectively few of the most obvious negative impacts (child labor, minimum wages) and incorporate development goals where local communities share sustainably in the potential economic benefits from biofuels in comparison to current alternatives.

Biofuel sustainability and food security: Missing links

Another limitation of the prevailing biofuel certification schemes is the lack of inclusion of small scale farmers. By design, certification schemes favour large-scale agribusinesses as they require costly procedures with significant amounts of information and resources and also because big players have the means and incentives for scaling up production to absorb the certification costs. Moreover, larger companies typically already keep records needed for audits, but small-scale farmers often keep no written records on yields, fertilizers and by-products – data that is needed for the GHG estimations.

There are several ways to enhance smallholder inclusion, including enhancing the capacity and skills of small-scale producers to master compliance requirements (such as record keeping, facilitating farmers aggregations into producers organisations to reduce certification costs and to adopt more efficient and sustainable technologies that can facilitate certification. Though there are some incentives to address prohibitive certification costs for smallholders by some of the leading feedstock roundtables, a more sustainable solution is to ensure a more balanced representation of these roundtables, with active participation of smallholders' representatives in these multi-stakeholder certification schemes. The assessments of sustainable soy in Brazil and Jatropha in India showed that smallholders generally have good knowledge of on-farm conservation, but not the same options to extend native vegetation buffer zones. Similarly, field burning – an important emitter of GHGs – is mainly practised on small farms, while many large plantations have already mechanized their production and can easily respond to this pollution issue.

Biofuels for poor developing countries: bridging food with energy security

Much of the focus about biofuel industry moving south has been on leveraging foreign direct investments (FDI) to bring large scale capital intensive biofuel plants closer to feedstock production sources, especially in developing countries presumed to have abundant land, water and/or labour resources. The drive behind biofuel FDI in developing countries has been essentially driven by cost cutting and efficiency enhancing objectives. Yet despite the many touted advantages of biofuel investments for rural development, energy security and employment, serious obstacles to biofuel growth remain in developing countries, including a lack of qualified labour, basic infrastructure and the investment capital needed to develop feedstock supply chains. Much of these requirements are beyond the capacity of many developing countries, especially among the poorest. Even assuming FDI is forthcoming, this still require an infusion of complementary and investment commitments from national governments to assure success and viability. Even under the best situations, one can expect smaller positive spillover impacts on the local economy because labour and capital are imported while biofuel is produced for export. There is also the issue of land acquisition for large scale biofuel projects and the potential conflict with existing or traditional land rights, access and use. This concern have become acute enough since the food crisis of 2007-08 that FAO, along with other international organisations, developed a new set of guidelines for land access (Voluntary Guidelines on the Responsible Governance of Tenure of Land, Fisheries and Forests).

An alternative model that can contribute both to food and energy security for many developing countries would be based on the promotion and development of small-scale biofuel or bioenergy systems that can be integrated into existing farm, household or community development activities. Such systems (e.g. biodiesel-fuelled cooking stoves, solar lanterns and biodiesel-fuelled small power stations for electricity or small-scale irrigation) can be more effective in providing energy security for small-scale producers and local communities, especially in poor developing countries that traditionally rely on unsustainable exploitation of biomass which aggravates deforestation. An example of such a model is the integrated food-energy system (IFES) widely practiced in some South East Asian countries such as China and Vietnam with long tradition of closely linked livestock-fishery-crop intensive systems . Such biofuel development model could boost agricultural and land productivity, raise land productivity, secure more rural employment opportunities, and offer greater positive economic impacts on local communities, compared to large-scale biofuel production systems that rely imported capital and skilled labour and export the produced goods with fewer multiplier effects on the local economy. However, an IFES like system would require an active policy support in line with national strategies that integrate energy needs with food security and long term sustainable rural development. For poor countries, such strategy could also be supported by ODI, international development agencies and through bilateral aid funding including funds for climate change mitigation and adaptation.

Large scale biofuel production (ethanol, biodiesel) could also be included as part of national energy strategy, depending on the country's industrial capacity, energy needs, and comparative advantage (land abundance, established feedstock value chains (ex: palm oil-biodiesel in Malaysia; Cassava-ethanol in Thailand..etc). The key criteria however is that the strategy must be dictated by domestic food and energy security needs, with trade playing a complementary role in case of excess supply.

Final conclusions and ways forward

This report presented a broad-based global assessment of the biofuel sustainability challenge, yet it is by no means exhaustive, and other related questions remain to be tackled.

For example, biofuel development is also facing, with increasing urgency, the rising challenges of climate change and the need to account for carbon footprints and to reduce GHG emissions. How should the initial concern of biofuel certification be expanded to include carbon footprint certification, or are these separate concerns? Are the social criteria of these existing certification schemes compatible with the recently endorsed Voluntary Guidelines on the Responsible Governance of Tenure of Land, Fisheries and Forests by the World Committee on Food Security? How could these voluntary guidelines be implemented within the existing biofuel certification schemes?

Overall, the increased awareness and pursuit of biofuel sustainability has gained momentum in recent years which in itself is a positive development. However, the assessment of the core biofuel sustainability issues and the certification schemes showed the limitations of the processes followed and the lack of an integrated approach. Moreover, there is a huge gap between the conceptual definitions of standards, principals and criteria and actual testing and verification on the ground. Clearly the voluntary private-led certification schemes are not sufficient instruments to ensure a balanced and an integrated coverage of the essential elements of sustainability be it economic, environmental or social. Strong public complementary public policies including incentives, disincentives and regulations are needed to ensure a more balanced treatment of sustainability challenge, safeguard the mobilised resources, and enable smallholder inclusive value chain development processes.

What is needed is rethinking a new approach that integrate sustainability with the pursuit of renewable energy strategies and food security that is inclusive of marginal and small scale stakeholders. What is required as a more coherent and integrated framework for sustainability that combine both private schemes and public regulations in such a way as to assure inclusive processes, between large enterprises and small scale producers, as well as between northern and southern countries goals and interests.

Rethinking sustainability also require incorporating full environmental costs in economic cost-benefit assessments and fostering business models that can reconcile sustainability with economic growth and integrate inclusive-development with food security. Also required are policies, regulations and incentives that broaden the biofuel development options to include small-scale locally harnessed renewable energy technologies and systems. Finally, biofuel sustainability will need to be mainstreamed into larger trends towards sustainable and climate-smart agriculture in line with the triple objectives of enhanced productivity, strengthened food security and climate change adaptation and mitigation.

General introduction

Biofuels date back to the late 19th century, when ethanol was derived from corn and Rudolf Diesel's first engine ran on peanut oil. Until the 1940s, biofuels were seen as viable transport fuels, but falling fossil fuel prices stopped their further development. Interest in commercial production of biofuels for transport rose again in the mid-1970s, when ethanol began to be produced from sugar cane in Brazil and since 1980's from corn in the United States. During the 1990s, the industrialized economies of North America and Europe actively pursued policies in support of domestic biofuel industries to achieve energy security, develop a substitute for fossil fuels and support rural economies. More countries have since launched biofuel programs, and over 50 countries have adopted blending targets or mandates and several more have announced biofuel quotas for future years.

Reducing the use of fossil fuels and greenhouse gas emissions rank among the key objectives in support of bioenergy developments. Yet, expanding biofuel production comes at a cost, mainly concerning food security and land use conflicts. Large-scale cultivation of feedstock crops may be at the expense of food crops, thereby inflating the prices of food products, endangering food security and fomenting social strife. Furthermore, the drive toward greater efficiency through higher yields and hence intensification of production, places greater stress on resources and generates unintended consequences by way of pollution and land degradation.

The need to address the growing challenge of climate change has led to closer scrutiny of biofuels to assess whether they can be produced, traded and used sustainably. While some biofuels might help reduce greenhouse gas emissions and improve the air quality in cities, the overall impact of biofuels on GHG reductions is not straightforward and depends very much on the type of feedstock used, production system adopted, direct and indirect land use changes, and potential effects on biodiversity and deforestation. Moreover, the food crisis of 2007-08 and the ensuing surge of commodity prices heightened the debate over food versus fuel and the possible consequences of biofuel production on food security. The potential of biofuels to contribute to a shift into more sustainable energy systems was contested, and scientists started to question the environmental superiority of biofuels.

As a result of these concerns, sustainability became an essential condition for biofuels long-term viability and for continued public support of biofuels as part of the solution to renewable energy conversion and climate change mitigation. In practice, this has been approached through a range of biofuel certification schemes, all purporting to ensure sustainability. Yet these schemes also seem to be driven by the need to regulate the current and potentially huge future trade in feedstocks and biofuels between industrialized economies (which have high potential excess demand for energy) and developing countries (which have recognized comparative advantages in biomass production and huge potential excess supply).

This report addresses the central issue of biofuel sustainability using a global assessment of major commodities and feedstocks currently employed for bioethanol and biodiesel production. The *approach for this report was guided by two overriding considerations. First, sustainability of biofuels hinges on understanding the full economic, environmental and social impacts of biofuels and feedstocks taken together and in relation to direct and indirect implications for land-use change, food security and climate change. Second, the recent trends in certification schemes for biofuel sustainability are influenced by considerations of trade and market access and the need to regulate the potentially huge flows of feedstocks (e.g. palm oil, sugar cane, corn, soybeans) and biofuels between consuming (i.e. industrial) and producing (i.e. developing) countries.*

This study examines in detail the implications for the three core dimensions of sustainability (i.e. economic, environmental and social) and offers a critical evaluation of the biofuel certification schemes in relation to sustainability. The report is global in scope and surveys a large number of representative case studies aimed at shedding light on the sustainability issues examined. It focuses on current biofuel production systems as well as the major biofuel sustainability initiatives and certification schemes.

The report is divided into three chapters. The first chapter provides a broad economic overview of the major feedstocks used to produce liquid, solid and gaseous biofuels. An analysis of each feedstock is presented, including a general overview of its production, energy and other input requirements, productivity and efficiency of biofuel generation. Chapter 1 also includes a review of country case studies focusing on a key biomass-biofuel pair. These case studies offer an in-depth analysis of the specific context for the various sustainability aspects of the feedstock under review. Chapter 2 addresses sustainability, presenting a detailed discussion of its three core dimensions: economic, environmental and social. Chapter 2 also review country and inter-government sustainability initiatives relative to biofuels and bioenergy. Chapter 3 provides a broad overview of the biofuel certification schemes and critically evaluates the degree to which these schemes can achieve sustainability, ensure development objectives and food security and contribute to inclusive growth and climate-change mitigation. The report is based on an extensive review of literature augmented with direct communication with selected experts on related topics.

Chapter 1

Crops for biofuels: Economic and technical assessment for sustainable production and utilization

The objective of this chapter is to provide an overview of the main biomass feedstocks: their production characteristics, resource needs, management requirements and relative efficiency in generating bioenergy. This information constitutes the techno-economic background needed for a more in-depth sustainability assessment of the feedstock-bioenergy combination in a particular locality.

The main feedstocks will be discussed under three broad headings: solid, liquid and gaseous biofuels (see Table 1.1). Discussion of each category will begin with a general review of the key feedstocks in terms of cultivation and technology, global production and trade potential, followed by illustration with in-depth case studies, taking note of feedstock input characteristics and utilization as a first step in assessing their potential for meeting sustainability criteria.

In the medium to long term, utilization of biomass is expected to rise considerably, provided sustainability challenges, competition for food and feed use and productivity of food and biomass feedstock are addressed (Bauen et al., 2009). In the long run, the trend toward clean, renewable energy will increasingly hinge on commercialization of dedicated energy crops such as switchgrass, miscanthus and short-rotation tree crops, currently the subject of substantial research and development (R&D). A section of this chapter discusses characteristics of second generation feedstocks and assess their implications for sustainable bioenergy.

1.1 Sugar crops

Among the sugar crops, sugar cane, a perennial grass, is the most widespread ethanol feedstock. It is grown in tropical climates in latitudes of 30 degrees south to 30 degrees north (Clay, 2004, s. 159). The stem, from which the sugar is retrieved, can reach up to 4 metres in length (Griffee, 2000).

1.1.1 Sugarcane

Among the sugar crops, sugar cane, a perennial grass, is the most widespread ethanol feedstock. It is grown in tropical climates in latitudes of 30 degrees south to 30 degrees north (Clay, 2004, s. 159). The stem, from which the sugar is retrieved, can reach up to 4 metres in length (Griffee, 2000).

TABLE 1.1 - SUMMARY OF BIOENERGY PROCESSES, BIOFUEL TYPES AND FEEDSTOCK SOURCES

	Liquid biofuels				**Solid biofuels**	**Gaseous biofuels**
Principal feedstocks	Starch crops Maize Wheat Cassava ...	Sugar crops Sugar cane Sugar beet Molasses Sweet sorghum ...	Oil crops Soybean Sunflower Rape seed Jatropha Oil palm Animal fats Waste oils ...	Lignocellu-losic biomass Bagasse Wood, Straw Agricultural wastes Algae ...	Forest and agricultural residues, wastes	Solid and liquid bio-fuels, forest and agricultural residues, wastes
Refining process	Glucose hydrolysis yeast fermentation	Yeast fermentation	Trans-esterification	Cellulose hydrolysis Biomass-To Liquids (BTL)	Pyrolysis, compression	Anaerobic digestion, gasification
Bioenergy	Bioalcohols (ethanol, butanol, propanol) (ETBE), Bio-oil		Biodiesel	Second and third generation biofuels (e.g biohydrogen, biobutanol, bio-methanol Fischer-Tropsch diesel)	Pellets, charcoal, biochar	Biogas, syngas
Principal end uses	Transport sector				Heat and power	Heat and power, transportation

Sugarcane field in Brazil (Source: FAO/Giuseppe Bizzari)

Sugarcane ethanol plant in Brazil (Source: FAO/Giuseppe Bizzari)

Sugar cane can be grown on various types of soils. It requires fertilizers with a high level of nitrogen and potassium, but a rather low level of phosphate. A typical constraint for sugar cane production is availability of water. The climatic conditions are ideal for sugar cane production in Brazil and other tropical regions (above all in Latin America and Africa), because the plentiful precipitation eliminates the need for irrigation, which is not the case for other sugar cane-producing countries (such as India, Australia, Peru, and South Africa).

In drier regions, irrigation is necessary as a means to bridge temporary water shortages, which increases costs, reduces the environmental benefits and can put pressure on scarce water resources (Kojima and Johnson, 2005). The production in the world's second largest sugar cane supplier, India (FAO, 2009a), suffers from water shortages; the country has little interest in expanding its sugar cane production to extract biofuels because of food security concerns. Accordingly, only molasses is used for ethanol, and a lot of effort is being put into developing non-edible feedstocks (primarily Jatropha) (Kojima et al., 2007).

Some of the most important factors in determining ethanol yields are cane tonnage, sugar content of the cane and the cane quality (FAO, 2009b). For the ethanol production process, energy demand is generally low (or neutral, as a result of the heat and electricity produced from the bagasse). A substantial amount of water is required to clean the feedstock (de Oliveira et al., 2005). Ethanol yield from sugar cane in Brazil can reach 85 litres per tonne of wet cane or 6000 litres per hectare (Goldember et al., 2008). In the European Union, the yield amounts to 5060 litres ethanol per hectare (Rajagopal et al., 2007) or 86 litres per tonne (CGEE, 2008).

Besides ethanol/diesel and sugar, sugar cane is the source of a wide range of by-products. Paturau (1986) listed over 35 uses that could be economically attractive. The filter muds obtained from the cane juice can be used as animal feed, cane wax and fertilizer. Also the vinasse, boiler ashes and molasses can be used as fertilizer. Molasses can be used in the alcohol production process or in the chemical industry. The fibrous bagasse can be used to generate heat and power or as an input for the pulp industry. Bagasse is also used for the production of second-generation cellulosic ethanol. Other uses are as animal feed and for plastics (see also BNDES e CGEE, 2008).

Brazil is the world leader both in sugar cane and ethanol production with over 514 million tonnes of sugar cane per year (FAO, 2009a). Other top producing countries are India, China, Thailand and Pakistan. Many countries (Peru, for instance) achieve higher yields per hectare than Brazil. This is attributed to the widespread use of irrigation (IICA, 2007), among other factors.

Ethanol from sugar cane is already produced on a large scale in Brazil. In the near future, other large sugar exporters, such as Thailand, Guatemala and Australia may have land and production resources to increase their ethanol production. Examples include Colombia and the Caribbean (Nogueira, 2006; Worldwatch Insitute, 2007).

1.1.2 Sweet Sorghum

Currently, sorghum is the fifth most widely grown cereal crop in the world. The production of grain sorghum is widespread both in the Northern and Southern hemispheres, the largest acreages being concentrated in sub-Saharan Africa and India, where it is a staple crop, providing food, feed grain and forage, and is even used in industry as a fuel source (Kassam et al., 2012). The United States is the largest producer, followed by Nigeria and India. Many African countries are also among the top producers, and the proportion of total agricultural land assigned to the crop

Box 1.1: Country case: Sugarcane ethanol - Brazil

Brazil's favourable growing conditions and its tradition for culturing sugar cane – one of the most efficient raw materials for the production of ethanol – were essential for developing ethanol as a biofuel. The Brazilian government's massive investment in infrastructure and research between 1975 and 1989 allowed the country to become a leader in the ethanol market.

After the 1973 oil crisis and following the rising import oil bills, Brazil turned into alternative fuels and started investing in ethanol through the National Alcohol Programme (Pro-Álcool) to increase ethanol production as a substitute for gasoline.

The tropical climate with abundant rainfall in the summer and dry and cool winters makes the cultivation conditions ideal for the state of São Paolo where most of sugar cane is produced. The feedstock is typically grown in large monocultures with two harvests a year. As of 2009, there are 421 plants in operation crushing (MAPA, 2009) 494 million tons of sugar cane per year (UNICA, 2009b), approximately one half being used for sugar and the other half for ethanol production. There is no significant small-scale production of sugar cane ethanol in Brazil (Walter and Segerstedt, 2008).

Brazilian sugar cane yields amount to about 84.7 tonnes per hectare (São Paolo) (Orplana, 2007). On average, about 122 kg/ha/yr of fertilizers, 1.9 tonnes/ha of lime (mainly for planting), 2.2. kg/ha of herbicides and 0.16 kg/ha of insecticides are applied. Harvesting is 50 percent mechanized (Macedo and Seabra, 2008) and hardly any irrigation is used.

The heavy reliance on nitrogen fertilizers adds to sugar cane's impact on climate and results in water pollution, leading to eutrophication of coastal waters and estuaries. Pesticides add to the pollution build-up in rivers and streams. Furthermore, for every litre of ethanol, 10-13 litres of a residue called vinhoto/vinasse or stillage are produced, which has the potential of contaminating rivers and groundwater if not properly managed.

The burning of sugar cane fields is still widespread, causing damage to the soil and high loss of nutrients due to escape of carbon and nitrogen compound gases. This practice adds to greenhouse gas emissions as well as causing serious problems for the local population including respiratory diseases related to smoke and ash.

Brazil has established several legal framework to factor in environmental protection regulating ethanol production. An example of such regulation is the Environmental Impact Assessment and Environmental Licensing, especially for the implementation of new project. Example, new green field projects in Brazil are being stringently assessed using these frameworks. Volunteer adherence to Environmental Protocols plays a role for the sugar business. For example the Agriculture and Environmental Protocol for the ethanol/sugar industry signed by UNICA and the Government of the State of São Paulo in June 2007 deals with issues such as: conservation of soil and water resources, protection of forests, recovery of riparian corridors and watersheds, reduction of greenhouse emissions and improve the use of agrochemicals and fertilizers. But its main focus is anticipating the legal deadlines for ending sugar cane burning by 2014 from previous deadline of 2021.

can be significant. Also displayed is the considerable variation in yields for grain sorghum, for instance from 3,440 Hg/ha in Niger to 54 100 Hg/ha in Argentina.

Sweet sorghum (*Sorghum bicolor* (L.) *Moench*) is an annual grass crop with stalks that can reach a height of 1 to 5 metres. It is grown in a similar way to conventional grain sorghum. Unlike sugar cane, with its requirement for fertile and deep soils, sweet sorghum is a highly versatile crop, adaptable to limited water and poor, shallow soils; it can be cultivated in tropical, sub-tropical, and temperate regions. Compared to sugar cane and sugar beet, sweet sorghum is drought-resistant, and the growing cycle is shorter: four months compared to 10-12 months for sugar cane (Reddy et al., 2007b). Production can be labour-intensive or completely mechanized. It generates almost equal yields of grain as grain sorghum, and similarly there is much variation in potential yields: for example, experiments in Iran show that biomass yields can range between 24 to 140 tonnes/ha and the sucrose content varies between 7.2 and 15.5 percent (Reddy et al., 2007b). Achieving good yields may require higher inputs of pesticides and fertilizers as well as tillage and irrigation (IFAD, 2007).

Although it has been traditionally used as an animal feed, sweet sorghum is a multi-purpose crop and its cultivation still at an initial stage. It is known for its significantly higher sugar content in the stalk and it is now bred for its high yield of sugar per unit of land and not for its grain.

On the negative side, it needs to be processed rapidly after the harvest and the biomass is rather bulky (with over 70 percent water content). Consequently, transportation and storage may pose a challenge. Moreover, as Brittaine (2008) observed, the processing plants are typically large, requiring high initial investments, so good infrastructure and efficient organization between the producers in the value chain are required.

New sweet sorghum varieties are being developed for bioenergy, the ethanol being attained from the lignocellulose-rich stalks after fermentation of the sweet sorghum juice. Ethanol yields have been estimated at 760 litres /ha from the grain, 1,400 litres/ha from the stalk juice and 1000 litres/ha from the residues (Reddy et al., 2007). Costs are about 50 percent lower for large biofuel plants, but pilot studies show that small-scale production could be viable as well. As with all sugar crops, one drawback is that the feedstock needs to be processed almost immediately after harvest: it tends to lose its sugar content if not processed within three weeks, thus constraining storage and transport. As with sugar cane, sweet sorghum juice can also be used for sugar production. The remaining bagasse can be used as feed, pulp or as fertilizer, but its most common function will probably be for co-generation of heat and power (Sipos et al., 2009). There is also the possibility of transformation into pellets (pelletization) for use as fuel. (Grassi et al., 2004).

China, India and the United States have already begun to produce sweet sorghum ethanol on a trial basis, and have invested significantly in continued research. Sweet sorghum hybrids under development are especially suited for production in tropical regions where drought or crop rotation restrictions limit sugar cane production; research in India has resulted in the release and distribution of germplasm of these hybrids. These sorghums have been tested and are now being used at ethanol production plants in India. They are being evaluated in other regions as well. In the southern African region, Zambia, Mozambique and Malawi could have a high potential for sweet sorghum-based ethanol production. (Watson et al., 2008 and Zhao et al., 2009).

Little research has been done on the sustainability of sweet sorghum as a bioenergy feedstock, but the grass has many sustainability characteristics, not least its high adaptability to tropical and sub-tropical as well as temperate areas. It requires little nitrogen fertilizer (about 100-200 kg/ha per year), and it is also possible to intercrop with legumes, which would further reduce the fertilizer requirement and add to the food supply. Additional advantages of the feedstock are the low water requirement and the high tolerance for flooding and for acid and saline soils (Grassi et al., 2004). Sweet sorghum has a shorter growing season than sugar cane and requires less labour (0.2 jobs per ha per year, compared with 1.0 for sugar cane). From an economic point of view, production costs could be lower than for any other biomass (IICA, 2007). Sweet sorghum provides both a cane yield (40 and 25 tonnes per ha per harvest) and a reasonable amount of grain[1] ; hence bioenergy production can be combined with food and feed production (ICRISAT, 2007) and the wastewater from the ethanol production process has been shown to be less hazardous than molasses (ICRISAT, 2007). In India, where grain sorghum production has declined due to the low economic returns and the general preference for other food crops, the adoption of sweet sorghum for energy purposes could be a welcome alternative (IFAD, 2007).

ICRISAT (2007) referred to an energy balance of 8.0 (which is close to the energy balance of sugar cane, 8.3), while dos Santos (1998) had far more conservative results: between 0.93 and 1.09. An estimation of the potential of sweet sorghum biofuels to reduce GHG in Mozambique showed a saving potential of 1 515.99-1 203.58 t CO2eq per year when it is used for electricity energy generation. However, there is still need for more research in this area.

A study was commissioned by FAO in 2009 to quantify the energy and GHG impacts along the entire life-cycle of sweet sorghum for a number of production and use systems, study additional environmental impacts from sweet sorghum cultivation, and compare technical aspects of sweet sorghum with other biofuel-generating crops [Köppen, Reinhardt, and Gärtner, 2009). The determining factors used to assess such impacts were choice of land, agricultural inputs, production methods, yields, and use of by-products.

In light of the on-going debate surrounding competition between bioenergy and food, this FAO study comes out in favour of sweet sorghum cultivation, for its multiple uses: as food, as first- and second-generation bioethanol, and as fertilizer. This assessment is based on currently-existing cost-efficient conversion technologies and the appreciable yields of sweet sorghum on soil that is marginally suitable for food crops (in contrast with many fully-established energy crops such as corn). First- and second-generation bioethanol from sweet sorghum contributes significantly to mitigation of greenhouse gases: between 1.4 and 22 kg carbon dioxide equivalents depending on yield per cultivation area, production method, type and efficiency of conversion technology, use of by-products such as bagasse, land cover prior to sweet sorghum cultivation, and land use changes. Even if only the seeds are used as food, bioethanol from the stem's sugar juice displays clear advantages for reducing use of fossil fuels. If both sugar and seeds are consumed as food, the associated energy and greenhouse gas expenditures could be compensated by producing second-generation ethanol from the bagasse. Using some of the bagasse to generate process energy (green electricity) would render production of first- and second-generation bioethanol self-sufficient in energy consumption.

The study further confirms certain facts regarding sweet sorghum: its low water

[1] 1 and 2 tonnes per ha for the first and second harvest compared with 3 and 2 for grain sorghum (ICRISAT, 2007)

Sorghum field (Source: FAO/Cendon)

demand makes it particularly suitable for arid zones; its low fertilizer demand reduces the risk of nutrient leaching and resultant soil and water pollution, and enhances its adaptability to small-scale subsistence farming conditions; its short vegetation cycle allows double cropping and possible concomitant savings in fertilizer and pesticide due to increased agro-biodiversity.

In common with many other biofuels, sweet sorghum-based ethanol ranks poorly against fossil fuel equivalents with respect to: acidification, eutrophication, (agricultural run-off carrying fertilizers by which nutrients accumulate and cause severe reduction on water quality), photochemical smog and ozone depletion.

For sustainability certification and emissions trading purposes, and the attendant need to calculate specific energy and GHG balances, the FAO study calls for future research to center on improving carbon sequestration in the crop parts and in the soil under different production systems and optimizing composition of single crop parts; the exact requirement for and yield response to mineral fertilizer under specific soil and climatic conditions; and integrating the crop into low-input/carbon-poor soil cultivation systems.

Agronomic and industrial trials in Europe, Asia and Africa have demonstrated the productive potential of sweet sorghum as part of new bioenergy systems that integrate sweet sorghum with sugar cane to supply both ethanol and electricity. The fibrous residues obtained from the extraction of sugars from sweet sorghum stems have similar properties to sugar cane bagasse and can be used in the same way to produce electricity, process heat and power. Sweet sorghum's rapid growth and its ability to reach maturity in three to five months allow it to be planted on fallow sugar cane land (at most 5 percent of total sugar cane area) for harvesting and processing before the start of the sugar cane planting season.

Thanks to intensive agronomic research over the last decade in Australia, Brazil, China, India, the United States, Zimbabwe and Europe, sweet sorghum (Sorghum bicolor L. Moench) has emerged as a viable feedstock for fuel ethanol production. The sugars in its sugar-rich stems can be extracted and fermented to produce ethanol for use as a liquid fuel, primarily for transport purposes as well as in ethanol-fuelled lights and cookers. The feedstock production requires about 10 kg seeds, 100 kg fertilizers and 3 kg insecticides per ha. For two harvests, approximately 8,000 m3 of water per ha per year is also required. Suitable soil textures range from clay to sand, but the argillaceous/sandy-argillaceous soil of the central regions has the highest potential.

The biofuel yields for sorghum may range between 0.21 and 0.6 tonnes per ha (Econergy International Corporation, 2008). Potential production costs of sorghum ethanol have been estimated at US$ 0.27 per litre of ethanol (US$ 0.45 when adjusted to gasoline equivalent), although these estimates should be considered approximate, since they are based on grain sorghum (Econergy International Corporation, 2008).

1.2 Starchy crops

1.2.1 Maize

Maize (also referred to as corn) can be grown in many different locations, although most of it is cultivated in temperate climates. Compared to other food crops, it is highly productive: under the right conditions the agricultural output is higher than any other cereal (between 7-11 tonnes per ha) and ethanol yield can reach 3500 litres per ha of corn (Ecocrop, 2009). Fertilizer and pesticide requirements are high (EEA, 2006); however, for both feedstock production and the ethanol conversion process, water consumption is relatively low: 3-4 litres of water per litre of ethanol produced

Corn field (Source: FAO/Napolitano)

(Aden, 2007). The energy consumed in the conversion process amounts to 41.60 GJ per ha of maize (de Oliveira et al., 2005).

On a global scale, ethanol accounts for approximately 8.4 percent of global maize production (OECD, 2008a). Maize is the largest feedstock for liquid biofuel production, although almost all the biofuel is produced in the United States.

The sharp rise in US ethanol production in recent years has meant a high demand for maize as the feedstock of choice. Compared to sugar cane, however, maize offers lower ethanol yields per unit of land, and maize ethanol is typically costlier than sugar cane ethanol. Maize is also one of the biofuel feedstocks with the highest pesticide and herbicide input per ha (see e.g. EEA, 2006).

Moreover, the sharp rise of maize demand in recent years in response to the growth of the US ethanol industry has had significant impacts on commodity prices, in the United States and through trade

Box 1.2: Country case: Sweet sorghum ethanol - Mozambique

Sorghum's ability to survive limited inputs of water and nitrogen fertilizer, as well as its tolerance for salinity and drought stress have made it the crop of choice for farmers in drought-prone regions. According to FAOSTAT data for 2007, Mozambique has an arable land area of 4.45 million ha, of which 0.3 million ha or 6.74 percent is devoted to grain sorghum. In the higher food-deficit regions of Mozambique, grain sorghum provides the staple food for both humans and livestock. Most of the production is concentrated in the region of Zambezia (36%), followed by Nampula (19%), Sofala (13%) and Cabo Delgado (10%) (Uaiene, 2004).

Grain sorghum is mainly produced in small-scale farming systems, consisting of 1-2 ha plots. Inputs are generally available only to farmers with external support (from the government or NGOs). A study of the Mandica district in Mozambique revealed that 90 percent of households were producing for their own consumption, with the remaining 10 percent selling or transferring their crops to family members living elsewhere (Uaiene, 2004).

Temperatures in Mozambique range between 20.5 and 30 °C. Rainfall amounts are from 975-1474 mm per year in the northeast, but only 475 mm per year in the southwest (FAO, 2009c). According to an estimate by Johnson (2007), at least 16 percent of the country's total land, in the center and north of the country – which includes mostly rural and poor areas with high unemployment rates – could be suitable for sweet sorghum production, based on agro-ecological conditions as well as the availability of water. That estimated percentage could rise to 28 percent, if there is a high level of inputs. Suitability reflects both agro-ecological conditions as well as the availability of water resources.

The International Energy Agency estimated Mozambique's sustainable biofuel potential to be around 6.7 exajoules per year (the equivalent of around 3 million barrels of oil per day), with moderate introduction of agricultural technology and using strict sustainability criteria. Considering the sum of feedstock and refining costs, sweet sorghum is the lowest-cost option for producing bioethanol in the country, followed by molasses, sugar cane and cassava. Mozambique is one of the two least developed southern African countries (the other being Malawi). Because they are starting at very low levels of commercial energy they stand to benefit the most in terms of the percentage of current energy supply that can be met by sweet sorghum. After an initial push for Jatropha, since 2004, interest shifted to sugar cane and more recently to sweet sorghum.

As of July 2007, the Mozambican government committed itself to the promotion of biofuels as part of the national poverty alleviation agenda. In March 2009, the Mozambican government approved a national policy and strategy for biofuels. Some of the important political and strategic pillars are: proposed limits on land allocation to biofuel production on the basis of suitable agroclimatic regions through land zoning; approval of selected feedstocks, namely sugar cane and sweet sorghum for ethanol, and coconut and Jatropha for biodiesel; the use of sustainability criteria to select investment projects and allocate land titles; the creation of a domestic market for biofuels via blending mandates, which will be gradually phased in at increasing levels; increase export to create tax-revenues and foreign currency; the promotion of regional markets for biofuels; and the establishment of tariffs for the purchase of electricity produced from biomass, particularly cogeneration of electricity as a by-product of the ethanol production process (Schut, Slingerland, and Locke, 2010).

Box 1.2 (*Cont'd*)

Although the cultivation of sweet sorghum from seed is not very labour intensive, at 0.2 jobs per ha per year (Econergy International Corporation, 2008 and ICRISAT, 2009), the development of biofuels-related activities in these regions could generate income and create opportunities for employment. It could also carry considerable socio-economic risks, especially concerning food security and land appropriation: large-scale cultivation of feedstock crops may compete with that of food crops, inflate the prices of food products and reduce access to land by smaller farmers. New land brought into production for extensive cultivation of biofuels must be carefully selected to ensure that existing cultivation is not displaced, which could jeopardize food security and create disruptions to Mozambican society.

C4 crops, including sweet sorghum, thrive in the tropical and sub-tropical climates of southern Africa, and a large, well-established sugar industry based on sugar cane has been developed. Out of Mozambique's total cropland area of 78.4 million ha, 28 000 ha was under sugar cane, as of 1999 (Woods, 2001).

Compared to sugar cane, sweet sorghum's lower input costs (for water, fertilizer and pesticides) and increased tolerance of environmental stress make it particularly suitable for smallholder farmers. It requires one-third less water per unit of above-ground biomass (and hence per litre of ethanol produced) than sugar cane, which makes it well-suited to drought-prone sugar-producing regions of the world.

By extending the length of the harvesting and milling season in existing sugar cane processing facilities, along with its efficiency of land use, water, equipment, personnel, and other resources, sweet sorghum can be rendered economically viable as a source of bioenergy to meet about 3 percent of the region's electricity consumption and one-third of the liquid fuel consumption (gasoline and diesel). This level of bioenergy production would require that the equivalent of 1 percent of existing cropland (arable and permanent), be dedicated to the growth and processing of sweet sorghum.

When processing sweet sorghum, it is important to minimize the time between harvesting and processing. Sweet sorghum, a relatively short-season crop compared to perennial sugar cane, is more susceptible to seasonal climatic variations and significant year-to-year yield fluctuations. Unless key biomass "quality" thresholds are attained, sweet sorghum may be too difficult to process in existing sugar mills without major modifications.

High-yielding varieties of sweet sorghum have been developed that are capable of producing well over 100 tonnes (fresh-weight of above-ground biomass) in five months under good agronomic conditions, compared with 150 to 200 tonnes over 12 months for sugar cane. However, these yields, achievable only where climate, water and nutrient inputs are optimal, and pests and diseases are fully controlled, have not yet been demonstrated in southern Africa.

The potential quantity of sweet sorghum that could be harvested from 5 percent of Mozambique's sugar cane land is 64 400 tonne sorghum stems, generating 4830 MWhe, and as much as 18 034 070 tonne sorghum stems with a potential energy yield of 1 352 555 MWhe could be harvested from 1 percent of cropland; sorghum electricity could meet 167 percent of total national energy consumption. A key pre-requisite for realizing sweet sorghum's full potential in countries such as Mozambique is a continuation of the trend from "top-down" to "bottom-up" community-based resource management.

internationally – an issue particularly debated during the recent 2007-08 food price crisis. In the United States, the cultivated maize area rose by 19 percent between 2006 and 2007 (Goldemberg and Guardabassi (2009)

Maize ethanol has also been criticized for its purported lower GHG emission savings. Farrell et al. (2006) used a meta-model approach to compare the results of six studies and found that maize ethanol produced in the United States emits approximately 13 percent less GHG than fossil fuels. A more recent study by Liska et al. (2009) found higher GHG emission savings for US maize ethanol, in the range of 48 to 59 percent, and an energy balance between 1.5 and 1.8. The authors argued that their better outcomes resulted from using more recent values for important input factors.

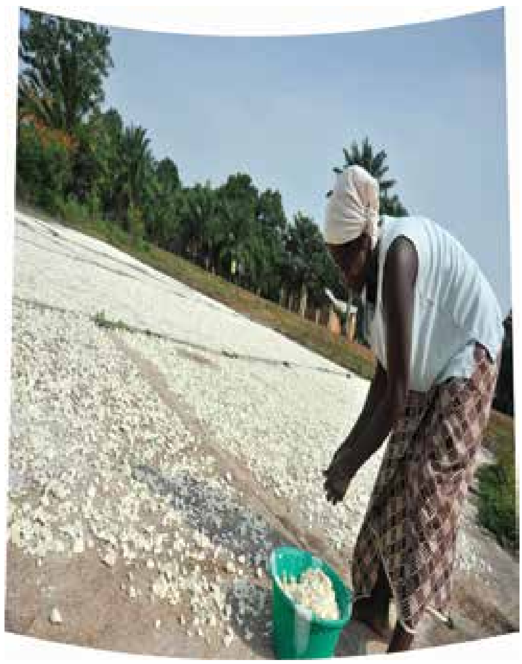
1.2.2 Cassava

Cassava (also known as tapioca or yucca) is a perennial tuber crop cultivated mainly in Africa, but also in Asia and Latin America.

Cassava is a drought-resistant crop, with a good capacity to overcome pests and diseases. It reaches a height of about 1-3 metres, and there can be numerous roots on each plant (Tonukari, 2004). Cassava can be grown on both sands and clays, and is tolerant to soils with limited fertility (Facius and Ipsen, 2006). Cassava is cultivated in the tropics and sub-tropics where precipitation is above 600 mm in a cycle of at least 2-3 months (Lokko et al., 2007). The four largest producers are Nigeria, Brazil, Thailand and Indonesia, accounting for about 50 percent of world production.

Cassava yields can be very high – up to 90 tonnes of fresh roots per ha. However, at present production is generally on marginal land as a complement to other crops such as maize and beans. As a result, the average yield only amounts to 9.6 tonnes per ha worldwide (7.7 tonnes in Africa; 12.7 in Latin America; and 12.9 in Asia) (CIAT, 2001, see also Fermont et al., 2009 for a longer discussion).

Cassava field (Source: FAO/Gangale)



Cassava drying (Source: FAO/Gangale)

Box 1.3: Country case: Cassava ethanol - Thailand

Thai cassava is grown on 1.15 million hectares, corresponding to about six percent of total agricultural land (FAO, 2009a). In 2004, 55 percent of the cassava cultivation area was in the Northeast, 33 percent in the Central Plain and 13 percent in the north of Thailand (OAE, 2003).

The climate is characterized by unpredictable rainfalls during the monsoon period from May to October (on average 1200 mm per year). For the rest of the year, weather is dry (<100 mm per month) and droughts are common in the Northeast (Ratanawaraha et al, 2001). The average temperature is 27 °C. The soil texture is generally sandy or sandy loam with pH 5-6.5. Soil erosion is common as a consequence of intensive cultivation. The planting takes place between May and November, and the harvest during January to March or in October (Hillocks et al., 2002).

About 36 percent of the land cultivated with cassava is irrigated (Ratanawaraha et al, 2001) and experiments show that yields may increase substantially when irrigation is applied (Samutthong et al., 2007). About 200 kg fertilizers per ha with high potassium and nitrogen are recommended (e.g. 15-7-18) to achieve a yield of 15 tonnes per ha (Howeler, 2002). Land preparation is usually undertaken by tractor, and weed control with hoe, tractor and herbicides (FAO, 2001). Average yields in 2004 were 20.28 tonnes per ha, generating 3687 litres of ethanol (Nivitchanyong, 2007).

Cassava cultivation is based on a small-scale farming system in which land plots range between 0.5 to 2 hectares; large-scale plantations are prohibited by law. Cassava chips are usually produced in small factories owned by farmers or small manufacturers. The chips are sold to pellet factories or used for animal feed as well as ethanol feedstock (Sriroth et al., 2006). About 96 worker-days per ha is required out of which 50 worker-days are covered by family labour (Ratanawaraha et al, 2001).

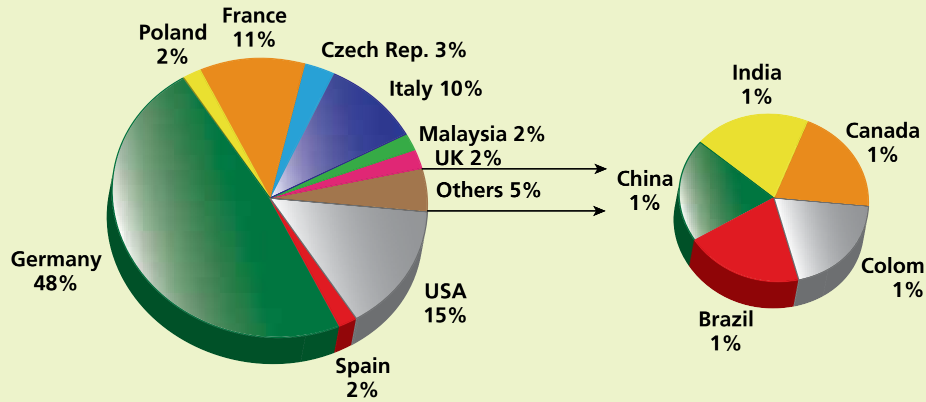
In 2008, total production of cassava roots was expected to be 27.45 million tonnes, with 34 percent for cassava chips/pellets, 49 percent for starch and 17 percent for ethanol (Sriroth et al., 2006). As of 2009, 5 out of 17 local ethanol producers use cassava as feedstock (the others use sugar cane molasses) for ethanol production).

As with sugar crops, cassava roots decay rapidly after harvesting and immediate processing is necessary. The most important use of cassava in Africa is for food. In sub-Saharan Africa, it provides 12 percent of daily calories per capita (FAO, 2009a). A major use is as cassava starch that can be used as input ingredient in the food industry, as sweeteners, or for ethanol, paper and citric acid. Cassava can also be processed into chips or pellets (to produce 1 kg chips about 2-2.5 kg fresh root is required). The chips are used for feed and ethanol as well as for citric acid production. Ethanol yields from cassava vary from 137 to 190 litres per tonne fresh cassava or 3 705 to 6 313 litres per ha (JGSEE, 2009).

1.3 Biodiesel feedstocks

After ethanol, the second most important liquid biofuel is biodiesel made out of fats and vegetable oils such as rapeseed, sunflower, and soy. The yields of typical biodiesel feedstock are considerably lower than the ethanol yield from sugar and

FIGURE 1.1 - GLOBAL BIODIESEL PRODUCTION 2006



Source: REN21, 2008

starchy crops, with the exception of palm oil grown in the tropics (OECD, 2008b). The EU is by far the world's biggest producer of biodiesel, and there is some external trade, especially in the direction of the EU (from US).

1.3.1 Rapeseed

Rapeseed (also referred to as canola) is an annual/biennial herb that grows well in temperate regions, ideally under 500 mm of rainfall. It can attain a height of 0.5-2 metres. Yields are usually between 0.5 to 2 tonnes per ha, although 2-4 tonnes per ha are also possible (Ecocrop). The oil content of dried seeds is 45 percent (Bernesson et al., 2004). It is cultivated on fertile and well-drained land (Nielen, 2002). In Sweden, two litres of herbicide and 0.3 litres of insecticide are applied per ha every second year (Bernesson et al., 2004). Nitrogen fertilizer input is between 50 and 100 kg per ha, depending on whether it is an annual or biennial crop. The cultivation involves 13.9 worker-hours per ha (Koukios and Diamantidis, 1998), and production can be small- or large-scale (Bernesson et al., 2004).

The main uses of rapeseed are as forage, animal feed and vegetable oil. The oil can be used in food applications or as feedstock for biodiesel, soap and lubricants. The most important by-products are straw from cultivation (Koukios and Diamantidis, 1998) and glycerine from the biodiesel process. In spite of its low nutritional value, the rapeseed cake is often used for feed. Moreover, organic waste and wastewater can be used as fertilizer (Bernesson et al., 2004).

Due to Europe's widespread cultivation of the crop and its dominant position in biodiesel production, rapeseed is the most important feedstock for biodiesel production on a global scale, accounting for approximately 59 percent of world biodiesel feedstock (Pahl and McKibben 2008). In Europe, biodiesel yield from rapeseed averages 1200 litres per tonne of rapeseed (FAO, 2008a).

1.3.2 Oil palm

The oil palm (Elaeis guineensis) is an important agricultural crop which yields three important sources of food and animal feed, namely palm oil, palm kernel oil and palm kernel cake. An average of 3.7 tonnes of palm oil, 0.4 tonnes of palm kernel oil and 0.6 tonnes of palm kernel cake is obtainable from one hectare of land. While the first two products can be used for human consumption, such as cooking oil, margarines, shortenings, bakery fats, vanaspati, ice creams, Vitamin E and other products, palm kernel cake is used as an animal feed. Palm oil is also a source for biofuels (biodiesel) used for power plants, transportation fuel and other renewable energy purposes throughout the world.

Oil palm is a tropical forest plant, adapted to temperatures between 24 and 30 °C and 1780-2280 mm of rainfall per year. The stem reaches a height of 18-30 metres, and the crown typically comprises 40-100 leaves. If sufficiently watered, it can be cultivated on a number of soil types (although well-drained and deep soils are optimal). The yield ranges from 15-30 tonnes of fresh fruit bunches and 15-25 percent extractable oil per ha per year. The variability is largely attributable to the efficiency of pest and disease management as well as methods of harvesting, transport, storage and processing. Breeding and selection have led to considerable improvements and some scholars suggest there is a high potential to improve yields even further (Sheil et al., 2009 and Griffee, 2008).

The palm fruit, which is comparable to a plum in size and grows in bunches of up to 2000 fruits, comprises a kernel (endocarp) surrounded by mesocarp and pulp. The edible oil is retrieved from the pulp, while the kernel provides oil that is primarily used in soap production. Both types of oil can be used for biodiesel production. When the oil is extracted from the fruit, empty fruit, mesocarp fibre and shells are collected for other potential uses, e.g as ameliorant or to extract molded oil palm, which is used in furniture and in many industrial applications. The empty fruit bunch can be used in the paper and pulp industry. The stem is useful as wood but can also be used for electricity generation, together with empty fruit bunches and oil palm fibres. The palm fronds are converted into animal feed or left on the field to improve the soil quality and the oil palm

Oil palm field (Ghana) (Source: FAO/Elbehri)

Box 1.4: Country case: Oil palm biodiesel - Malaysia

Malaysia's humid climate with a temperature range of 24-32 °C throughout the year and evenly distributed annual rainfall of almost 2000 mm is ideal for oil palm cultivation. Originating in West Africa, oil palm was initiated in the 1960s to complement rubber as part of the Malaysian government's anti-poverty efforts. This was carried out by resettling landless farmers on holdings mainly growing oil palm. A total of 853 000 hectares of plantations are managed by the Federal Land Development Authority (FELDA) providing employment for 100 000 farmers.

In 2006, Malaysia produced about 15.88 million tonnes (43 percent of world total) of palm oil from 4.17 million hectares. This represents close to 48 percent of the agricultural area in Malaysia planted with oil palm and about 860 000 people employed in the oil palm industry. Palm oil exports represented the third largest contributor to Malaysia's external trade earnings following electric/electronic and crude petroleum (MPOB, 2007).

Oil palm plantations are dispersed throughout Malaysia occupying 2.34 million ha (56%) in Peninsular Malaysia, 0.59 million ha (14%) in Sarawak and 1.24 million ha (30%) in Sabah region. Malaysia has a total of 397 mills, 51 refineries and 17 oleochemical plants processing oil palm (MPOB, 2007). The ownership of planted areas is as follows: 59 percent as private estates, 30 percent government or state owned and 11 percent smallholder plantations. Approximately 90 percent of the area planted in 2006 was considered mature (UNDP, 2007).

According to the Malaysian Palm Oil Board (MPOB), the increase in oil palm area in Malaysia results from planting of idle (deforested) land or converting from other crops. From 1990 to 2000, oil palm area increased from 2.029 million ha to 3.377 million ha, reaching 4.17million ha in 2006. Less than half of the additional land came from other crops, mostly from rubber (which declined from 1.836 to 1.121 million ha from 1990 to 2006) but also from cocoa (from 0.393 to 0.032 million ha in the same period) and coconut (from 0.134 to 0.142 million ha). Over 50 percent of added oil palm land came from idle (peat soils) or deforested lands (MPOB, 2007).

The farming system can be described as follows: smallholders (<40 ha, with an average of 0.5-3 ha); new land development schemes; and large-scale commercial plantations (>40 ha). New land development schemes have been introduced by the public sector. The largest public agency that manages Palm oil, FELDA, has land holdings of 4.04 ha for oil-palm and rubber (FAO, 2004). Plantations employ labour all year, because of continuous harvest, the peak season being between April and September.

For acid soils, 2-4 tonnes of limestone per ha are applied every two years. On average, oil palm removes 192, 11, and 209 kg per ha per year of nitrogen, phosphorus and potassium, respectively (assuming a yield of 25 tonnes fresh fruit bunches per year) (FAO, 2004). Herbicide is also applied to control weeds (Wibawa et al., 2007).

In comparison to other oil crops, oil palm requires fewer inputs of agrochemicals and fossil fuel. Table 1.2 compares input-output parameters for oil palm with soybeans and rapeseed crops.

In the past, mineral soils have mainly been used for oil palm production, but the use of peat soil has increased in the last decades (Sugandi, 2003). Some 8 percent of the country's area

Box 1.4 (*Cont'd*)

TABLE 1.2 - INPUT-OUTPUT IN CULTIVATING OIL PALM AND OTHER CROPS

	Inputs to produce one tome of oil by the crop		
	Palm oil	**Soybean oil**	**Rapeseed soil**
Seed fruit extraction (kg)	4 500	5 000	2 500
Inputs			
■ Nitrogen	47	315	99
■ Phosphate (kg P205)	8	77	42
■ Pesticides/herbicides (kg)	2	29	11
■ Energy (Gj)	0.5	2.9	0.7
Output			
Emissions to soil/water:			
■ Nitrogen	5	32	10
■ Phosphates	2	23	13
■ Pesticides/Herb.	0.4	23	9
Emissions to air:			
■ NOx	0.5	4	0.8
■ SO_2	0.2	2	0.3
■ CO_2	0.1	6	2
Output/Input (energy: Gj/ha)	182/19	50/20	70/12

Source: FAO, 1996

(3 million ha) is covered with peat. Sarawak, the largest state in Malaysia, has the biggest reserve of peatland: about 1.5 million ha that is relatively underdeveloped. Peatland is also found in the West (0.8 million ha) and Sabah (0.1 million ha).

Peat soil in its natural state, poorly drained and waterlogged for most of the year, has generally been considered a problem soil with marginal agricultural capability. However, its rather homogeneous nature, the constant availability of water and its flat surface render peat soil suitable for oil palm development, providing uniform yield characteristics.

The conversion of peatlands to oil palm for biofuel production and use, which invariably involves draining, will result in significant CO2 emissions and will counter any carbon benefits that palm-based biofuel may offer: it is estimated that each hectare of peat swamp forest drained and converted to oil palm may contribute 3304 tonnes of CO2 over 30 years. It could take around 420–840 years to recover this 'carbon debt'.

A prominent case of carbon debt is the impact of increasing palm oil production on peatland areas in Malaysia and Indonesia. Due to the high water tables, peat forests contain a high degree of non-decomposed organic matter. Thus, although peatlands only represent about 3 percent of

Box 1.4 (*Cont'd*)

the global land surface, they may account for between 41 and 71 percent of all carbon stored in the terrestrial biota (Mitra et al., 2005).

For many crops, peatland is not appropriate and for a long time it was not very interesting for agricultural activities. But deep drainage of the forests makes palm oil plantations possible and in the last few years they have been spreading rapidly. Drainage causes decomposition as well as CO2 emissions and increases the incidence of fire, which magnifies the problem even further. Since 1997, drainage has been estimated to have emitted 2 trillion t/CO2 in Indonesia, out of which peatland fires were responsible for about 70 percent (Tan et al. 2009).

The oil palm produces two oils from its fruit: palm oil from the mesocarp and palm kernel oil from the kernel. An oil palm bears fruits within 30 months of planting and will continue doing so for up to 30 years.

According to Oil World (2007), the average oil yield for oil palm is around 3.74 tonnes//ha/year compared to 0.38 for soybean oil, 0.48 for sunflower, and 0.67 for rapeseed. It was shown that a palm oil plantation can produce up to 36.5 tonnes of dry matter/ha/year compared to 25.7 tonnes/ha/year by natural rainforest.

The Malaysian Government has implemented the National Biofuel Policy and approved the Biofuel Industry Act in 2007. It mandates the use of B5 (5% of RBD palm olein and 95% diesel) for transport. Support policies include tax incentives for the construction of biodiesel plants and exemption from export duty of processed palm oil (including biodiesel) (Hoh, 2008). Malaysia has been diverting a large share (up to 40%) of the crude palm oil to biodiesel production. Over ten plants had been built with a capacity of one million tonnes. Most of the biodiesel is exported to Europe and the U.S.

kernel cake is sometimes used for feed. Finally, various residues obtained from the oil extraction can be used to obtain biogas or as feedstock in the chemical industry (Sumathi et al., 2008).

The largest oil palm producers are Indonesia and Malaysia, accounting for more than 80 percent of global production. Papua New Guinea and Nigeria, where oil palm is an indigenous plant, also dedicate a large share of their respective agricultural areas to the feedstock. However, unlike in Malaysia and Indonesia, where large plantations are common, Nigeria's production is mainly based on small-scale farming and semi-wild palms. Accordingly, yields are much lower (Vermeulen and Goad, 2006).

Palm oil accounts for about 10 percent of biodiesel production, which is expanding at a fast pace mostly from Indonesia and Malaysia (Pahl and McKibben 2008). Investments have also been made in, among others, Thailand and the Republic of Congo (Pleanjai and Gheewala, 2009 and Reed, 2009). In Malaysia, biodiesel conversion averages 2500 litres per tonne of crude palm oil (FAO, 2008a), each tonne of oil requiring 3.5 tonnes of harvested palm (Subramaniam et al., 2008).

1.3.3 Soybean

Soybean is an annual legume. The majority is grown in temperate regions and the sub-tropics, but production is increasing also in tropical areas where rainfall ranges from 600 to 1500 mm annually. Soybean is generally cultivated either in mono-cropping plantations, such as in Argentina, or bi-annual rotations, as in the US Midwest. The planting system is generally mechanized (Kulay and da Silva, 2005). Soybean is usually rainfed and fairly resistant to drought, at least for short periods (Merrill, 2000). In most countries, limited or no irrigation is used, and input of fertilizer and pesticide is minimal (Hill et al., 2006). Since soybean is a legume, usually no additional nitrogen is needed. The average requirements for phosphorus and potassium in Canada are 23 and 60 kg per ha respectively (Rollefson et al., 2004). The optimal growing conditions for the plant are alluvial, well-drained soils with a high level of organic matter (Escobar et al., 2009).

World average soybean yields are about 2300 kg per ha (FAO, 2009a). Oil content is around 17.5 percent. Soybean oil yield per ha is relatively low compared to tropical oils (such as palm oil)[2] .

Soy oil is the third most important biodiesel feedstock after rapeseed and palm oil. In the United States, it accounts for 75-90 percent of total biodiesel production (Carriquiry, 2007), and many countries that have introduced biodiesel blending targets are expected to rely on soy-based fuels (e.g. Brazil, Argentina, Paraguay and Bolivia).

Biodiesel production from soy amounts to about 25 percent of global biodiesel production, and soy is the second largest biodiesel feedstock after rapeseed (Pahl and McKibben, 2008). The United States is currently the largest producer, but is expected to reduce its share in total production from 16 percent to 11 percent due to lower profits and export possibilities in the EU (FAO 2009d). Brazil and Argentina are projected to have the largest future

[2] The US Department of Energy estimates a yield of approximately 375 litres per ha (compared with 5800 for oil palm) (Beckman, 2006).

TABLE 1.3 - SOYBEAN AND SOYBEAN OIL YIELDS, BY-PRODUCTS AND PRICES

Period: Oct/Sept	Soybean and soybean products: prices				
	Soybean[1]	Soybean oil[2]	Soybean cake[3]	Soybean methyl ester	Glycerine (in US)[6]
	USD/mt				
2002					1 764
2006/07	335	772	264		816
2007/08	549	1 325	445		992
2008/09	422	826	385		
2009/10	429	924	388		
2010/11	549	1 308	418		
2012				932 [4]	
2012				1 484 [5]	

Source: FAOSTAT, 2011

[1] Soybeans: US, No. 2 yellow, c.i.f. Romtterdam.
[2] Soybean oil: Dutch, f.o.b. ex-mill
[3] Soybean cake: Pellets, 44/45 percent, Argentina, c.i.f. Rotterdam
[4] c.i.f. price (Europe port)
[5] f.o.b. price (US), Soy Methyl Ester Manufactures (Alibaba.com)
[6] www.abginc.com

Box 1.5: Country Case: Soybean Biodiesel - Argentina

Soybean plantations are distributed across 16 100 hectares, which is equal to 12 percent of the total agricultural area (53 percent of the grain area). As much as 83 percent of the production takes place in the central region, namely Buenos Aires, Córdoba and Santa Fe. Lately, increasing profitability has led to cultivation in more isolated areas in the northeastern and western areas (van Dam et al., 2009a, FAO, 2009d).

The average annual temperature in the central area is between 10.5 and 20 °C and precipitation is between 475 and 1474 mm a year (FAO, 2009e). The time of the harvest depends on the type of soybean; first-class soybean is sown between October and November and is harvested between April and May. After the harvest, the land is set aside for the winter months. Second-class soybeans are usually sown in December and harvested in April or May, after which the land is used for wheat cultivation. Because first-class soybeans are grown during the optimal growing cycle, higher yields are generated. In contrast, second-class soybeans offer the possibility of two harvests (Panichelli et al., 2008).

The yields of around 2826 kg per ha per year are among the highest in the world. With an oil content of around 18 percent, it is possible to extract 500 litres/ha of oil, out of which 502 litres/ha of biodiesel can be produced (Tomei and Upham, 2009). Panichelli et al. (2008) estimated an average use of nitrogen fertilizers of 5 kg/ha (monoammonium phosphate), only for first-class soybeans, and of phosphorus fertilizers of 5+10.5 kg (monoammonium phosphate and triple sugar phosphate). No potassium fertilizer is applied. Soybean is sensitive to pests and weeds, and a number of pesticides are used, mainly glyphosate (for a complete list, see the source). Irrigation is very limited.

The main cost category for the biodiesel production is the cultivation (64 percent), followed by administrative costs (18 percent) and labour costs (7 percent). In total, the cost of producing 1m3 biodiesel from soybean, after discounting the value of glycerol, amounts to US$ 346.96 (Asal et al., 2006).

Both first- and second-class soybeans are based on monocultures or intercropping with maize and sunflower (Panichelli et al., 2008). The industry has become more and more concentrated over the years: in 2007, 60 percent was produced by 4 percent of the suppliers (Tomei and Upham, 2009). Small and medium-large farmers are usually organized into cooperatives or stocking companies that link them with the oil extractors (van Dam et al., 2009a). Small farms require about 1 job per 8 ha, but large-scale farms are highly mechanized and may not need more than 1 job per 200 ha (Tomei and Upham, 2009).

potential in view of their land availability and low production costs (Kline et al., 2007). Using US data, biodiesel production from soybeans requires 13.6 litres of water per litre of biodiesel (Gerbens-Leenes et al., 2009b) and produces 375 litres of biodiesel per ha (Beckman, 2006)

1.3.4 Jatropha curcas

Jatrophia is a drought-resistant, non-edible perennial: similar to cassava, it can be grown on marginal land with limited water and agrochemical supply. Optimum growing conditions are found in areas of 1 000 to 1 500 mm annual rainfall, with temperatures of 20°C to 28°C with no frost, and where the soils are free-draining sands and loams with no risk of waterlogging. Propagation is typically from seed.When fully grown, it reaches a height of 3-4 metres. It can grow into a tree 6 metres high or taller; however, for harvesting purposes, height is kept at or around 2 metres, with a gestation period of 2-3 years (Altenburg et al., 2009). Apart from its drought tolerance, it offers the advantage of restoring soil and controlling erosion. Moreover, it is suitable for intercropping, especially during the first two to five years before it starts to yield fruit (see e.g. Jongschaap, 2008).

According to a study carried out by the Global Exchange for Social Investment (GEXSI, 2008), there are currently about 250 Jatropha projects running globally on a total area of around 900 000 hectares. The bulk of this area is concentrated in Asia (85%), followed by Africa (13%) and Latin America (2%).

Yield estimates vary considerably, depending on the site and the growth conditions. Achten et al. (2007) estimated an output of dry seed of 1-2.5 tonnes/ha/year for degraded land and low amounts of input. Fertile soils and high inputs were expected to produce 2-5 tonnes per ha per year. The oil content of the seed, extracted mechanically by means of oil presses or through chemical means, may vary between 27 and 40 percent (see also Jongschaap et al., 2007). Still crop improvement is at an early stage. Increasing oil yield must be a priority – an objective that has only recently been addressed by private enterprise. Genetic variation among known Jatropha curcas accessions may be less than

Jatropha field (Source: Centre for Jatropha promotion) previously thought, and breeding inter-specific hybrids may offer a promising route to crop improvement.

From a sustainability point of view, Jatropha could be a promising feedstock even where access to energy inputs is scarce. As it is inedible, it does not compete directly with food production.

Jatropha is toxic, and people in the tropical and sub-tropical areas have grown it for a long time to protect their fields against wild animals. Other traditional applications are as fertilizer (fruits and leaves), soap (seed oil) and medicine (leaves and latex) as well as for erosion control (Jongschaap et al., 2007).

Jatropha biodiesel is extracted from the seed oil. The husks and cake can be used as fertilizer or briquetted for heat and power generation. Fatty acids can be used to produce soap. By-products from the transesterification process are potassium fertilizer and glycerine (10 percent of total output). The seed shells can also be separated out ('decortication') for heat and power production and to obtain meal. The meal is protein-rich, but the toxic substances need to be removed to make it suitable as animal feed (Reinhardt et al., 2007). Biodiesel yield from Jatropha averages 340-795 litre/ha on barren land and 795-2840 litre/ha in normal soils (Weyerhaeuser, 2007).

TABLE 1.4 - WORLD JATROPHA ACREAGE IN 2008

Country	Acreage (1000 ha)
Myanmar/Burma	850.0
India	407.0
China	105.0
Indonesia	75.0
Madagascar	35.7
Zambia	35.0
Thailand	20.0
Tanzania	17.0
Brazil	15.0
Lao	11.7
Viet Nam	10.0
Mozambique	7.9
Malawi	4.5

Source: GEXSI, 2008
Trade in Jatropha is negligible at this point

The fact that it is possible to store and transport the fruit before processing makes it suitable for small-scale production. The majority of current Jatropha production is based on outgrower schemes or a combination of outgrowers and large-scale plantations (GEXSI, 2008). The oil subtraction is rather uncomplicated with low technological requirements. The subsequent processing to biodiesel, however, requires a higher degree of know-how and technical equipment, so a combined approach, integrating small-scale farmers and technological expertise, is customary. Apart from the income opportunities and the positive impacts such an arrangement might have on rural growth, another advantage is the possibility of local use of the oil, reducing fuel expenses and increasing public health.[3]

However, economic profitability of biofuels will require intensive crop management. While drought-resistant, Jatropha will only produce fruit if it receives sufficient light, nutrients and water. For example, as was observed by Prueksakorn and Gheewala (2008), lack of water might reduce the number of harvests to only one per year (reasonable yields were obtained at an average precipitation of 900-1200 mm). Their results also pointed to a large dependence on energy input for yield; Jatropha cultivated on poor land required double the amount of energy (mainly fertilizers and irrigation) to yield the same amount as when cultivated on fertile soil.

[3] e.g. by using it for cooking and heating indoors, where air pollution from conventional domestic cooking fuels (wood, charcoal, waste etc.) may contribute to serious health risk.

Box 1.6: Country case: Jatropha Biodiesel-Ghana

Jatropha is grown mainly in the northern parts of the country on around 5700 hectares. According to an estimate carried out by GEXSI (2008), Jatropha cultivation area could increase to 600 000 ha by 2015. The climate is beneficial for Jatropha cultivation, and wild trees are widespread.

The northern parts are semi-arid, with limited forest density, and low-to-medium climatic production potential. The southern parts have a higher level of rainfall and could bring higher yields. However, more land and labour are available in the north. For the entire country, average temperatures are between 30.5 and 35 °C and average precipitation is between 975 and 1474 mm per year (FAO, 2009f).

In the above-mentioned GEXSI study (2008), 67 percent of the farms evaluated used some kind of fertilizer (mainly seed cake, but also other organic and chemical fertilizers). Manual irrigation was used on 33 percent of the farms, while the rest did not use any irrigation at all. Intercropping was widespread. Yields for a large-scale plantation in the north were estimated to be 2600 kg crude oil per ha per year. Soap water was used to control beetles.

When the seed yield is 5 kg per tree and the oil extraction rate is 30 percent, the production cost per litre of crude biofuel is US$ 0.35. The biodiesel processing cost is around US$ 0.37, resulting in a total expenditure before taxes of US$ 0.72 per litre. By comparison, for a seed yield of 2 kg per tree and an oil extraction rate of 20 percent, the corresponding values are: US$ 0.71 per litre of crude biofuel, US$ 0.41 as biodiesel processing cost, and a total expenditure before taxes of US$ 1.12 (Caminiti et al., 2007). It is noteworthy that seed cultivation represents the bulk of the crude biofuel production cost: in the latter case, as much as US$ 0.51 out of US$ 0.71, with transportation and oil extraction accounting for the remainder. The cultivation model is based on plantations (33%), outgrower schemes (33%) or a combination of both (34%) (GEXSI, 2008)

This research suggests hat high yields require fertilizer and irrigation for efficient biodiesel production on marginal land (see also van Zon et al., 2006).

1.4 Dedicated energy crops (algae, waste)

Plants are made from lignin, hemicellulose and cellulose; second-generation technology uses one, two or all of these components. These biofuels can be manufactured from various types of biomass. In theory, any lignocellulosic crop can be used for biofuel production. This includes cereal and sugar crops, specifically grown energy crops, agricultural and municipal wastes, cultivated and waste oils, and algae.

Common lignocellulosic energy crops include wheat straw, Miscanthus, short-rotation coppice poplar and willow. However, each offers different opportunities and still further research and trials are needed to consider any particular crop 'best' or 'worst'.

Dedicated energy crops offer many advantages:

- they contain high amounts of sugar that can now be turned into energy, thanks to advanced biomass conversion technologies;
- they produce higher volumes of fuel per tonne and per hectare compared with current biofuels;

- they can be grown on less productive land and closer to production facilities – delivering improved logistics, lower costs and reduced environmental and agricultural impacts;
- as perennial crops many of them efficiently recycle nutrients and can take carbon from the air and fix it into the soil, which helps to improve its quality over time.

Certain alternative feedstocks could well be used for both ethanol and biodiesel, and grown under varied climates and farming systems. It is possible that the many other plant materials that provide a much higher net energy gain for ethanol than corn will become economically feasible within the next five years. Also foreseeable are improvements in the conversion efficiency of existing feedstocks, such as wood and grass pellets.

One emerging alternative feedstock for ethanol is cellulosic biomass: the fibrous, woody and generally inedible portions of plant matter from perennial grasses, poplar trees and alfalfa. These generally require less intensive planting methods, integrate well into existing rotations and provide better soil cover and environmental benefits than annual row crops. Although no market exists at present, a leading candidate crop for cellulosic ethanol production is switchgrass, a long-lived herbaceous and perennial energy crop, which has received lot of research in the (Elbehri, 2008).

Another high-yielding large perennial grass which requires little input is Miscanthus, which is subject to intensive research in Europe and the United States. With yields of 22-33 tonnes per ha, Miscanthus is also excellent for carbon sequestration and soil building. Similarly, efforts are underway to render economically feasible alternative feedstocks for biodiesel that provide a higher net oil yield than soybean – for instance safflower, mustard and canola.

The development of future energy crops must be evaluated from the standpoint of their water use efficiency, impact on soil nutrient cycling, effect on crop rotations, and environmental benefits with respect to improved energy use efficiency and reduced GHG emissions, nutrient runoff, pesticide runoff and land-use impacts).

1.4.1 Algae

There are several algae-based biofuel (ABB) pathways both land-based and sea-based with widely varying opportunities and restrictions (FAO, 2009g). The former are more developed than the latter. In these ABBs many input sources can be used, like combustion gas, salt water and wastewater. ABB designs are also influenced by climatic conditions, such as annual solar irradiation and temperature.

ABBs have important sustainability implications, some are unique to algae. Large amounts of land with a low economic and ecological value can be used while fresh water usage can be avoided. Even more space opportunities exist in seas based systems and are available for ABB production. A key advantage from algae is the capacity to capture GHGs and reduce their emissions. Moreover several waste

Algae culture (Source: FAO/Berry)

streams can be treated, while at the same time being used as carbon and/or nutrient and/or water source.

ABBs main draw back at this time is their lack of economic viability as this industry is only at nascent phase and has a long road ahead before it reaches commercial stage (same with second generation or cellulosic biofuels). As yet, there are no commercial algae-based scale examples producing only bioenergy. Key economic obstacles include the bulk status of energy and biofuels which tend to have a low value. Moreover, algae cultivation and processing systems require a high capital input (higher than agriculture). Substantial cost cutting technologies are needed in the short and medium term and development of higher value co-products are needed to reach economic competitiveness and hence economic viability.

Algae based ABB systems may have a potential for developing countries but an ambiguous one. The high capital costs required and the large foreign investments leading to outflow of capital and the high technical know how all play against developing countries easily developing this new industry. On the upshot, to the extent that sea-based systems are labour intensive, this could prove beneficial to developing countries and rural communities.

Several companies and government agencies are funding efforts to reduce capital and operating costs to make algae fuel production commercially viable. Algae have a harvesting cycle of 1-10 days, which permits several harvests in a very short time frame, a different strategy from use of yearly crops (Chisti 2007). Algae can also be grown on land that is not suitable for other uses.

Research into algae for the mass-production of oil is mainly focused on microalgae –organisms capable of photosynthesis that are less than 0.4 mm in diameter, including the diatoms and cyanobacteria – as opposed to macroalgae, such as seaweed. The preference towards microalgae is due largely to its less complex structure, fast growth rate, and high oil content (for some species). However, some research is being done into using seaweeds for biofuels, probably due to the high availability of this resource.

The utilization of wastewater and ocean water instead of freshwater is strongly advocated due to the continuing depletion of freshwater resources. However, heavy metals, trace metals and other contaminants in wastewater can decrease the ability of cells to produce lipids biosynthetically and also affect various other workings in the machinery of cells. The same is true for ocean water, but the contaminants are found in different concentrations. Thus, agricultural-grade fertilizer is the preferred source of nutrients, but heavy metals are again a problem, especially for strains of algae that are susceptible to these metals. In open pond systems, using strains of algae that can deal with high concentrations of heavy metals could prevent other organisms from infesting these systems (Schenk et al. 2008). In some instances it has even been shown that strains of algae can remove over 90 percent of nickel and zinc from industrial wastewater in relatively short periods of time (Chong, Wong et al. 1998).

Technical problems, such as harvesting, are being addressed successfully by the industry but the high up-front investment of algae-to-biofuels facilities is seen by many as a major obstacle to the success of this technology. Only a few studies on the economic viability are publicly available, and these must often rely on the little data (often only engineering estimates) available in the public domain.

1.4.2 Waste

Urban waste and some waste by-products rich in biomass also can be used as feedstocks for biofuel production.

Wood dust (Source: FAO/Gallagher)

Three of the main categories are discussed below. These are: municipal solid waste, food processing waste, and black liquor.

Municipal solid waste – the component of municipal solid waste that are of biological origin (e.g. kitchen and garden waste, paper, cardboard) comprises a very large range of materials, and total waste arising with significant opportunities to convert this waste to fuel via gasification or pyrolysis. There are also all kinds of wood by-products, such as construction/ demolition wood (i.e. wood offcuts from building construction and wood recovered during demolition), packaging waste wood (e.g. crates and other items from the packaging and palettes industries) and household waste wood (e.g. old furniture, fencing). There is also sewage sludge which can be converted to biogas via anaerobic digestion.

Food processing waste - include wastes from the dairy and sugar industries and from wine and beer production – may be converted to ethanol via fermentation. Waste cooking oils can be filtered and used as straight vegetable oil (SVO) or converted to biodiesel. Lignocellulosic (woody) or mixed waste materials may be converted to biocrude via pyrolysis/thermochemical operations. Thermochemcial processes may also be used to produce bio-jet fuel, biodiesel and bioethanol. The conversion technology used depends on the precise nature and volume of waste that is available and the end product. Waste streams with smaller volumes (e.g. orange rests from orange juice production) can also be of interest. Green waste, such as forest residues or garden or park waste, also may be used to produce biofuel via different routes (e.g. biogas captured from biodegradable green waste and converted through gasification or hydrolysis to syngas for further processing to biofuels via catalytic processes).

Another important feedstock source is black liquor – a by-product from the kraft process (which digests pulpwood into paper pulp by removing lignin, hemicelluloses and other extractives from the wood to free the cellulose fibres). Black liquor contains concentrated lignin and hemicellulose, which may be gasified with very high conversion efficiency and GHG reduction potential to produce syngas, which can be further processed to produce biomethanol or biomethyl ether (BioDME). Pulp mills have used black liquor as an energy source since at least the 1930s. Most kraft pulp mills use recovery boilers to recover and burn much of the black liquor they produce, generating steam and recovering the cooking chemicals (e.g. sodium hydroxide and sodium sulfide used to separate lignin from the cellulose fibres needed for papermaking). This has helped paper mills reduce problems with water emissions, reduce their use of chemicals by recovery and reuse and become nearly energy self-sufficient by producing, on average, 66 percent of their own electricity needs on-site. The black liquor gasification route has been shown to have very high conversion efficiency and GHG reduction potential, although the scale would be small.

1.5 Gaseous biofuels

Many modern biomass technologies require that solid and liquid biofuels be transformed into gas before they can be used in turbines. Gaseous biofuels are typically divided according to the production process: anaerobic digestion (generating biogas) and thermal gasification (generating syngas).

1.5.1 Anaerobic digestion

The anaerobic digestion process refers to the decomposition of organic matter in the absence of oxygen. As a result, biomass is converted into biogas, with a high proportion of methane and CO2. After improving the biogas (usually by separating the methane from the CO2¬ and the steam), it can be combusted to produce heat and power. When further processed, the biogas has properties close to compressed natural gas and can be used as a transport fuel. The solid and liquid by-product (digestate) can be applied as fertilizer (see e.g. Monnet, 2003).

A number of feedstocks are considered, all with moisture content between 50 and 99 percent. Agricultural residues are perhaps the most common source. However, the direct use of energy crops (generally grains and grasses) is gaining attention as well, especially in Germany and Austria. Moreover, anaerobic digestion is an important method for treatment of sewage sludge (often the only option available in developing countries). Use of industrial and municipal wastes is also increasingly widespread. Pilot projects in cities where food waste is separated from other waste have shown promise. Residues from the animal industry can also be used; however, as additional treatment is generally necessary, animal waste from slaughterhouses and food products is usually more suitable for larger plants (IEA, 2005).

As with other biofuels, production of biogas has increased rapidly in recent years. In Europe, both centralized CHP plants and decentralized systems can be found, while in the United States the focus has been on farm-scale operations. The technology has been extensively adopted in many developing countries, with the main focus

TABLE 1.5 - BIOGAS PRODUCTION IN SELECTED COUNTRIES (ESTIMATES) IN 2006

Country	Biomass gross production (1000 terajoules)
USA	162.2
Germany	69.7
Italy and San Marino	15.0
Spain	14.0
Australia	11.1
France incl. Monaco	9.5
Canada	8.0
United Kingdom	6.3
Netherlands	5.9
Republic of Korea	5.9
Japan	4.8
Denmark	3.9
Belgium	3.3
Czech Republic	2.7
Poland	2.6
Switzerland-Liechtenstein	2.5
New Zealand	2.3
Nepal	2.1
Finland	1.5
Austria	1.5

Source: UN Energy Statistics Database, 2009

Box 1.7: Turning waste into energy: Application of Integrated Food Energy Systems (IFES) to small-scale farming in developing countries

The concept of integrated food-energy system (IFES) consist of utilizing all by-products or residues in an agricultural production system for energy use (FAO, 2010b). This can be achieved through the inclusion of renewable energy technologies such as anaerobic digestion or gasification, which produce energy and soil amendments at the same time. Thus the IFES contribute to replacing fossil fuels (including fossil-based chemical fertilizers) with renewable energies for household activities or productive uses which will lead to considerable household savings.

Integrated Food Energy Systems (IFES) is divided into two types. Type 1 combine the production of food and biomass for energy generation on the same land, through multiple-cropping systems, or systems mixing annual and perennial crop species and combined with livestock and/or fish production (ecosystem approach). Type 2 seek to maximize synergies between food crops, livestock, fish production and sources of renewable energy, using agro-industrial technology such as gasification or anaerobic digestion.

Through IFES, smallholders and local communities in remote rural areas may improve their access to modern bioenergy through production of biogas, wood pellets, or vegetable oils and/or other sources of renewable energy. This may help improve farms' productivity through fuel or electricity powered equipment, irrigation, and transportation. In addition, this may lead to improved food storage and preparation as well as have positive effects on sanitation, health services, education and communication.

China and Vietnam are two countries with a long tradition of operating a closely livestock-crop integrated systems and where IFES systems are widely practiced (FAO, 2010c). These systems vary widely in shape, size and composition, starting from smallholder integrated crop-livestock -biogas schemes to medium, community scale livestock and biogas operations, to large-scale biogas plants near urban centers. However, more successful examples are found for simpler systems like biogas, but are relatively scarce for more complex IFES operations.
About half of Chinas farmers are currently using integrated crop-livestock systems and a growing percentage of them are IFES due to various subsidies from the Chinese government. However, both the central government and the private sector, are investing in research on how to integrate other forms of bioenergy production into existing farming systems such as the anaerobic digestion of straw and the production of bioethanol from sweet sorghum combined with livestock husbandry. Similar patterns are also found in Vietnam whose rural population combines livestock, fish and crop production in many parts of the country to date. In Vietnam too the IFES system has been supported by many programs led by different public bodies, international organizations, local NGOs and universities (see FAO, 2010c for more details on these two countries experience with IFES).

Clearly, where the required conditions are met, IFES can offer many tangible developmental advantages to farmers and local communities. The central conditions however is an established and closely integrated crop-livestock system, with abundant labour and scare land as is the case South East Asia. However, the optimal conditions for IFES may not be available everywhere. Moreover, agricultural by-products have many competing uses and may be readily be available as bioenergy feedstock without creating shortage elsewhere. Moreover, even assuming the initial

Box 1.7 (*Cont'd*)

conditions are met, such system would require policy support and incentives, including accessible and affordable credit to enable small scale farmers to acquire the needed technologies. Indirect incentives can also help, such as removing or reducing subsidies to chemical fertilizers or fossil-sourced energy as a way to stimulate demand for renewable.

Also the adoption of an IFES system (which can vary in degree of complexity) require special know how and hence the importance of farmers training and capacity building. Farmers many need to be knowledgeable in cash crops, vegetable and fruit production, animal husbandry, aquaculture, grassland management, forestry, carpentry and construction. The farmer may also need to have the technical knowledge needed to set up and maintain equipment such as digesters, gasifiers and generators. Even when the technologies needed to implement an IFES are reliable and economical, experience has shown that new technology can be rejected or abandoned if it is unfamiliar to those who may use it.

IFES may not appropriate or applicable everywhere. But when it can be applied and the required conditions are met, IFES should be promoted given the multiple development benefits it offers in terms of energy security, local rural development, employment, enhanced incomes for small scale producers, as well as a contribution toward climate change mitigation.

being on electrification of rural areas, heating and cooking, and waste treatment. In China and India, national programmes have existed for a long time (see e.g. Rajkumar Abraham et al., 2007, and Zeng et al., 2005). Biogas is also seen as a promising technology for landlocked areas such as sub-Saharan Africa, since it is relatively simple compared to other renewable energy technologies and allows for small-scale production (Amigun et al., 2008).

1.5.2 Thermal gasification

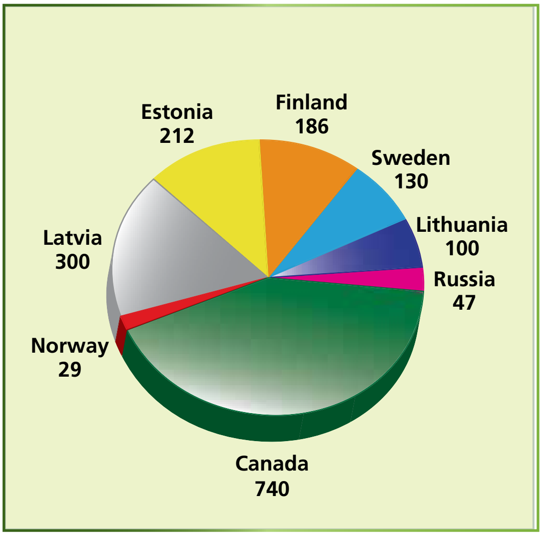
The anaerobic microorganisms that are responsible for the production of biogas cannot break down lignin found in woody plants. Gasification allows converstion of practically all biomass, including forest residues or even plastics. The feedstock is converted into char, which is then reacted with air, oxygen or steam. As a result, so-called synthesis gas (or syngas in short) is obtained: a mixture of carbon monoxide (CO), hydrogen (H2) as well as some CO2 and methane. One requirement for gasification is high temperatures (above 800 °C). Accordingly, it is efficient primarily for feedstock with low water content (not exceeding 10-15% before the gasification process). Other desirable properties are a low nitrogen and alkali content as well as a feedstock particle size of about 20-80 mm (depending on the furnace chamber) to reduce congestion (McKendry, 2002).

Thermal gasification is faster than anaerobic digestion, but has a relatively low conversion efficiency rate of 20-40 percent, although new technologies such as the Integrated Combined Gasification Cycle (IGCC) may increase this number to 50 percent. Existing plants are generally small (5-300 MW) and located close to the feedstock production site to reduce transport costs (Strezov et al., 2006). To overcome the high investment costs and increase the conversion efficiency, co-gasification with coal has become popular. The gas can be processed into liquid fuels such as ethanol, methanol, dimethyl ether or synthetic diesels (Digman et al., 2009).

1.6 Solid biofuels

The most common way to extract biomass energy is to combust the biomass directly. Modern technologies use steam to make turbines rotate and generate heat and power (or both). Various fuel materials can be applied for direct combustion: wood, municipal garbage, agricultural residues, etc. (Saxena et al., 2007). However, the bulkiness of the biomass constrains its storage and transport while its low energy content renders expensive the combustion of unprocessed feedstock. To avoid these problems, transformation methods such as the compression of biomass into pellets are frequently applied (Eubia, 2007). Pellets are usually made of sawdust and wood residues. In Northern Europe, where wood residues are abundant, the use of pellets

FIGURE 1.2 - GLOBAL PELLETS EXPORTS 2006/07 (000 TONNES)



Source: Bradley et al., 2009

TABLE 1.6 - WORLD WOOD PELLET PRODUCTION IN 2006

Country	Production (million t)	Share in world production
Sweden	1.5	21.5
Canada	1.4	20.6
USA	0.8	11.8
Austria	0.6	8.8
Germany	0.6	8.1
Rest of the world	2.0	29.3
World	6.8	-

Source: Peksa-Blanchard et al., 2007

has risen fast in recent years. Uses range from domestic heating in stoves or boilers to district heating and CHP plants. Briquettes are larger and are usually combusted in industrial devices (REAP 2009).

The largest wood pellet producer is Sweden, followed by Canada and the United States; together these countries account for over 3.5 million tonnes. Sweden is also the largest purchaser, along with some Central European countries, while the Baltic countries, Finland, Russia, Poland and Canada mainly produce for export. Countries with future export potential include Russia, Brazil, Argentina, Chile and New Zealand (Peksa-Blanchard et al., 2007).

Most of the pellets produced are made out of by-products from the forestry sector (Hadders, 2002). In the future, it is probable that other agricultural products will become more important, such as grass and agricultural residues. In Sweden, experiments with reed canary-grass have shown good results, while in Thailand and China, cassava and rice straw are gaining market share. Important factors for the choice of feedstock are energy content as well as moisture content/evaporation requirements. In view of the relatively high capital costs, cheap feedstock and high efficiency are required. (Nilsson and Bernesson, 2008).

1.7 Short-rotation crops

Short-rotation crops such as eucalyptus, poplar and willow have been an important source of firewood and charcoal for a long time. Recently, such plantations have experienced a revival in both temperate and tropical regions as many of them are considered good for biomass and biofuel production. A study conducted by The Center for International Forestry Research (CIFOR) (Cossalter and Pye-Smith, 2003) looked at the possible impacts such plantations might have on sustainability and found that major sustainability concerns with short-rotation crops are their impact on biodiversity, soil fertility and water availability. The impact on biodiversity depends to a large extent on the land use before conversion. While deforestation will generally lead to a decrease in biodiversity, the use of degraded land would improve biodiversity and contribute to a multiplication of species. In 2001, 6-7 percent of the decrease in natural forests was attributable to short-rotation crop plantations (with the most prominent cases in Indonesia). By contrast India and China have been successful in increasing the biodiversity on previously abandoned agricultural land. As with other crops, it is difficult to generalize but the effect depends largely on the site characteristics.

With regard to water requirements, short-rotation crops are usually planted in regions with abundant rainfall. If cultivated in drier climates, there is a possibility that the evapotranspiration of the plantations comes at the cost of important water streams, especially when grassland is converted into plantations. These impacts may be reduced by opting for species with lower water requirements as well as the practice of thinning.

Soil degradation and soil erosion are major problems especially in the tropics and subtropics. Because short-rotation crops are logged regularly, often with heavy instruments, the soil will be more affected than in the case of long-rotation forests. Although contour tree-planting and micro-catchments can help reduce the soil losses, these practices are not very common for short-rotation crops. Erosion is primarily a problem in the first years when the soil cover is low. The short growth period also has impacts on the nutrient status, especially during land preparation and logging. As was discussed in the case of sugar cane, post-harvest burning and removal of plant residues from the ground reduces the soil quality and should be avoided. On the other hand, short-rotation crops generally show a better result than crops such as cereals. Normally, they also require less fertilizer and there is little evidence for water pollution due to runoff.

Brazil, one of the countries with the highest number of short-rotation plantations, has mainly large-scale production, while other countries such as Madagascar have principally small-scale eucalyptus plantations. The short-rotation wood sector has been criticized for only providing seasonal employment with low security arrangements. However, large companies are increasingly trying to reduce costs and make planning more efficient by working on a continuous basis. Although it is difficult to estimate, the plantations create 1-3 job opportunities per 100 ha. If they help to reduce unemployment the net effect depends on what the land was used for earlier.

Short-rotation woody crops (SRWC) represent another important category of future dedicated energy crops; their use for bioenergy is not yet economically viable compared to alternative uses such as in the pulp and paper industry. Among the SRWC, hybrid poplar and willow have been extensively researched for their very high biomass yield potential, and breeding programmes and management practices are under continued development. SRWC are based on a high-density plantation system and more frequent harvesting (every 3-4 years for willow and 7 years for hybrid poplar). The wide genetic variation augurs well for increased yield. However, the economic viability of SRWC use for bioenergy is seriously constrained by high costs of establishment and lack of efficient mechanical harvesting techniques for high-density plantations (Elbehri, 2008).

The next section will detail two short-rotation crops: eucalyptus and poplar. Both are fast-growing, woody and lignocellulosic crops grown in short cycles that are currently gaining attention within the biofuels sector.

1.7.1 Eucalyptus

There are over 800 species of eucalyptus that grow in both temperate and tropical regions (Brooker, 2002). The most widely grown species for plantations, Eucalyptus grandis (with hybrids)[4] , can be found in tropical countries (Cossalter and Pye-Smith, 2003). The tree is an evergreen that reaches a height of 40-55 metres, sometimes up to 75 metres. With a trunk diameter of 120-200 cm, it is fairly drought-resistant for up to three months. An unexpected freeze or fire can be very harmful. Yields amount to between 17-70m3 per ha (Ecocrop, 2009). Logging usually takes place after 5-10 years (Turnbull, 1999). When grown in large-scale plantations, it is generally as monocultures with high productivity and rather small land requirements (Campinhos, 1999). The majority of the eucalyptus species are managed by coppice (Purse, 2005).

Coppicing is a traditional method of woodland management in which young tree stems are repeatedly cut down to near ground level. In subsequent growth years, many new shoots will emerge, and, after a number of years the coppiced tree, or stool, is ready to be harvested, and the cycle begins again. Coppicing offers the option of eliminating re-planting costs. Most eucalyptus species coppice freely, although

4 *E. grandis, E. urophylla, E. tereticornis, E. camaldulensis, E. pellita*

Eucalyptus trees (Source: FAO/Napolitano) there are exceptions. However, while coppicing may be superficially attractive, it may not be the most appropriate or cost-effective option in all situations – for instance, for certain types of biomass fuel.

The major uses of eucalyptus are for firewood, charcoal and hardwood pulp. The timber can also be used for telephone poles, construction, and mine prop and veneer (Ecocrop, 2009). Some species yield honey and essential oils that can be used in the chemical industry (Kashio, 1993). More recently, eucalyptus is also used in modern biofuel appliances, mainly for electricity, although the potential for second-generation ethanol is currently being explored (van Bueren and Vincent, 2003).

Industrial eucalyptus production is one of the fastest growing forestry sub-sectors, with Brazil as the major producer (Turnbull, 1999). Other large producers are Indonesia, China, India, South Africa, Thailand, Vietnam, Malaysia, Venezuela and Swaziland in the tropics and subtropics, and China, Chile, Portugal, Spain, Argentina, Uruguay, South Africa and Australia in temperate regions (Cossalter and Pye-Smith, 2003). Table 1.7 shows a rough estimate of world eucalyptus forests. Note that the numbers are not limited to short-rotation plantations.

TABLE 1.7 - WORLD EUCALYPTUS PLANTATIONS - 2005

Country	Area (1000 ha)[a]	Mean annual increment (m^3 pro ha and year)[b]
India	5 063	NA
Brazil	3 123	40.0
Vietnam	792	NA
China	663	NA
South Africa	557	20.0
Spain	460	10.0
Portugal	403	12.0
Peru	314	NA
Uruguay	278	NA
Argentina	249	NA
Chile	245	20.0
Pakistan	210	NA
Morocco	187	NA
Philippines	177	NA
Australia	160	NA
Madagascar	151	NA
Ethiopia	145	NA
Thailand	130	NA
Angola	128	NA
Rwanda	124	NA
Rest of the world	1 060	
World	**14 619**	**NA**

Source: [a]Coppen, 2002, [b]Campinhos, 1999

1.7.2 Poplar

Poplar (Populus trichocarpa or black cottonwood) exhibits some very desirable biocrop traits that make this species an ideal candidate for renewable biomass for energy production, reducing the need to use food crops as a raw material for liquid fuel production. The trees grow quickly, reaching maturity (17.5 – 20.0 meters high and 25 centimeters across) in six years. They have also demonstrated the ability to grow in some fairly poor soils, and with minimal attention. Furthermore, energy can be processed from them at cellulosic ethanol plants through a process that, not accounting for energy from fossil fuels, releases no additional carbon dioxide: cellulosic ethanol is a carbon neutral energy source.

Hybrid poplar in its present form could produce about 273 litres of fuel per tonne of wood. Approximately 22 tonnes of poplar could be grown per ha annually, representing 2 730 litres of ethanol. By comparison, corn currently produces about 9.9 tonnes per ha per year, with a yield of about 1 560 litres of ethanol. Changing the lignin composition could increase the annual yield to 8 580 litres of ethanol per ha.

In July 2009, scientists at Michigan Technological University proposed to develop poplar trees with roots that enable them to thrive in dry, infertile soils – marginal lands – thus avoiding competition with food production and curbing GHG

TABLE 1.8 - TRADE IN WOOD PULP - 2009

Country	Exports (1000 t)	Share in total exports (%)	Country	Imports (1000 t)	Share in total imports (%)
Brazil	8 586	19.10	China	13 578	28.90
Canada	8 275	18.40	Germany	4 591	9.77
Chile	4 310	9.59	USA	4 576	9.74
USA	4 043	8.99	Italy	3 002	6.39
Sweden	3 332	7.41	Republic of Korea	2 378	5.06
Indonesia	2 732	6.08	France	1 695	3.61
Russian Federation	1 715	3.81	Japan	1 665	3.54
Finland	1 458	3.24	Mexico	1 317	2.80
Portugal	1 149	2.56	Indonesia	1 131	2.41
Germany	1 049	2.33	Spain	923	1.96
Rest of the world	8 314	18.49	Rest of the world	12 123	25.80
World	**44 963**	**100.00**	**World**	**46 979**	**100.00**

Source: FAOSTAT, 2011

emissions through lower fertilizer use. The poplar was the first tree to have its entire genome sequenced. Researchers planned to screen the poplar's 45 000 genes to identify those that regulate its root system, particularly the genetic variations which might result in roots that seek out water and nitrogen more efficiently from the soil: the more efficient the roots, the bigger the trees, and the more biomass to turn into biofuel. After such identification, a variety of approaches, including genetic modifications and traditional breeding techniques, would be employed to develop the ideal poplar varieties for biofuel production on marginal lands while ensuring efficient nitrogen and water use, bringing the biofuel industry another step closer to environmental sustainability.

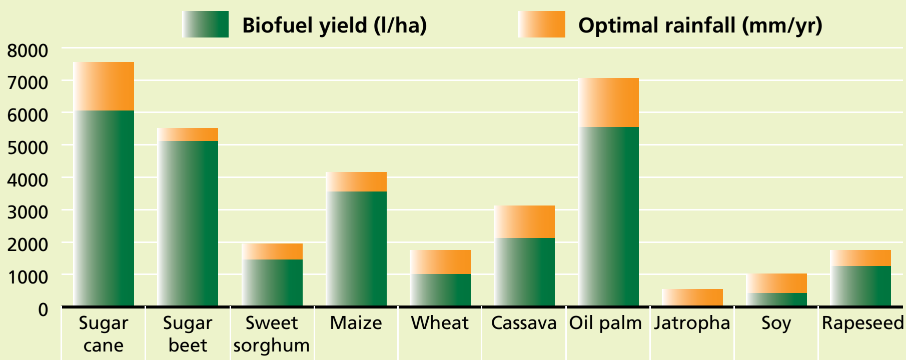
1.8 Overview of comparative efficiencies of different feedstocks

The input requirements and obtainable feedstock yields vary substantially between crops, production intensity, and locations. The table-graph combination (Figure 1.3) below shows a summary of optimal input requirements for ten different feedstocks: rainfall (mm/year) as well as the qualitative need for fertilizer and, for a few cases, that of nitrogen and agro-chemicals, and the biofuel yield (litres/ha).

With respect to biofuel yield (litre/ha), the feedstock with the highest yield is sugar cane (6000 litre/ha) while soy has the lowest yield (375 litre/ha). Some of the other feedstocks, in order of decreasing biofuel yield are: oil palm, sugar beet, maize, cassava, sweet sorghum, rapeseed and wheat; the yield from Jatropha is not available. Sugar cane and oil palm, although both high-yielding, are also demanding in terms of water. By contrast, sugar beet, while high-yielding and requiring little water input, requires a high level of nutrients and agro-chemicals.

The data for optimal rainfall (mm/year) indicate that the feedstocks most suited to wet (humid) zones are sugar cane and oil palm, which require 1500 mm/year, while sugar beet, which can thrive at a rainfall level as low as 400 mm/year, would be ideal for the more arid zones. As for fertilizer requirements (qualitatively speaking),

FIGURE 1.3 - BIOFUEL FEEDSTOCKS, YIELDS, LIFE SPAN AND INPUT INTENSITY



	Sugar cane	Sugar beet	Sweet sorghum	Maize	Wheat	Cassava	Oil palm	Jatropha	Soy	Rapeseed
Biofuel yield (l/ha)	6000	5060	1400	3500	952	2070	5500		375	1200
Optimal rainfall (mm/yr)	1500	400	500	600	750	1000	1500	500	600	500

Note: H=High, L=Low, M=Moderate, A=Annual, P=Perennial, B=Biennal

Sources: Data on biofuel yield, Rajagopal et al.(2007), FAO (2008a), Beckman (2006) and Reddy et al (2007a); data on rainfall and life span Ecocrop (2009); data on fertilizers, agro-chemicals and nitrogen Kimble et al. (2008).

sweet sorghum stands out as low while oil palm calls for a medium level. Sugar beet, maize, wheat and rapeseed all have high fertilizer needs. From this perspective alone, sweet sorghum will be the best 'candidate' feedstock for conditions in the least developed African countries, followed by oil palm. Sweet sorghum also stands on its own for its very high consumption of nitrogen as compared to sugar cane and sugar beet for which this need is high only in the initial period. Concerning use of agro-chemicals, maize is the only feedstock studied and its need is high.

1.9 Conclusion

While many feedstocks can be used to produce biofuels, this chapter focused on the most important ones currently in use. In addition, in order to align the feedstock review in this chapter with the sustainability discussion in chapter 2, a number of in-depth feedstock-country cases were presented, including Brazil (sugar cane, soy, eucalyptus), Malaysia (oil palm), Thailand (cassava), Ghana (Jatropha) and Argentina (soy). Key points about these feedstocks include the following:

- Sugar cane offers several advantages as a biofuel feedstock: (1) a high biomass yield per unit of land; (2) a large number of economically useful by-products; and (3) the potential for continuing its comparative advantage even when second-generation biofuels become economically viable (i.e. when bagasse also can be included as a feedstock). Sugar cane also offers the possibility for molasses by-products for biofuel, when sugar production is a priority (as in India). Rainfed sugar cane has been the predominant feedstock for ethanol production in Brazil. However, sugar cane consumes a lot of water, which poses sustainability problems in drier areas (i.e. it requires irrigation and competes with food crops for water use). Consequently, irrigated sugar cane may not be sustainable in the long run if irrigation derives from depletable underwater or aquifer sources.

- Sweet sorghum is the closest annual crop competitor to sugar cane in terms of potential yield per unit of land. Sweet sorghum is more attractive from a cost perspective than any other biomass feedstock because it requires only a short growing season, is drought-tolerant, has fewer labour requirements and produces high biomass yields. It is far more versatile than sugar cane and can be grown in a variety of soil depths and water conditions, while sugar cane demands deep soils and high water use and requires a full 12-month growing season. Sweet sorghum is particularly suitable in tropical areas too dry to grow sugar cane. On the downside, sweet sorghum requires quick processing after harvest because the sugar content drops significantly after only three weeks. This presents a challenge for transportation and storage given the bulkiness of the crop (70 percent water at harvest). Currently, sweet sorghum hybrids are being developed and tested in China, India and the USA for biofuel production.

- Maize for ethanol has the advantage of high productivity per unit of land, although it also uses large amounts of fertilizers and pesticides. Maize compares favourably with other feedstocks for ethanol, except for sugar cane which has a higher ethanol output per unit of land. The rising concern for climate change and GHG mitigation lessens the appeal of maize compared with sugar cane. Outside the USA, Canada and Europe, maize is used largely for food consumption. This is mainly why maize ethanol has tended to concentrate in the USA; very little maize ethanol is found in other producing countries (e.g. China) because of the direct fuel-food competition.

- Cassava is a staple food crop grown in Africa and Asia – especially in Africa, where cassava is among the top food-security crops south of the Sahel. Cassava has much higher yield potential than current averages, making it a prime target as an ethanol feedstock. However, a number of obstacles remain, including competition with food, the prevalence of small-scale production with limited processing capacity (because of high perishability) and the lower level of cassava value-chain development. Overall, outside of big Asian producers (e.g. Thailand), cassava continues to present serious obstacles as an ethanol feedstock.

- Rapeseed for biodiesel (which is like corn for ethanol in the USA) has been selected and promoted as the primary source of biofuel in the EU because of its suitability for cultivation in European conditions and because of the predominance of biodiesel in transport biofuel fleets in Europe. When the EU decided to promote the domestic biofuel industry for energy security, rapeseed for biodiesel was the primary target. Although more rapeseed is grown in Canada, China and India, only the EU has pushed for rapeseed-biodiesel production largely under heavy subsidies and mandates. However, in terms of biodiesel yield per acre or GHG savings, rapeseed feedstock doesn't compare favourably with other alternatives (such as palm oil). Consequently, very little rapeseed-biodiesel has been developed without policy support, and even within the EU, there has been some retreat from direct support to rapeseed-biodiesel on environmental and climate-change mitigation grounds.

- Soy oil is the second-largest biodiesel feedstock after rapeseed oil. Biodiesel production from soy oil is concentrated in the USA and Latin America (e.g. Argentina, Brazil, Paraguay). It is not produced in

China – a major soybean producer – because of the ban on food crops for biofuels and the fact that China is a net importer of soybeans. The largest expected expansion of soy oil for biodiesel is in Argentina and Brazil because of the availability of land and the relatively lower cost of production. However, soybeans in these countries tend to be grown under monoculture systems which pose sustainability challenges.

- Palm oil production and trade is expanding globally because of rising consumption, especially in developing countries. Among the current possible biodiesel feedstocks, palm oil is by far the most efficient source for biodiesel, far exceeding alternatives like rapeseed, soybeans or sunflowers. Most world production is concentrated in Indonesia and Malaysia, but major investments in new plantations are taking place in Africa and Latin America, driven by rising consumer demand, potential for expanded trade and opportunities for biodiesel production.

- Jatropha is a non-edible crop that can be used to produce biodiesel. It is drought-tolerant, requires low quantities of inputs and is suitable for marginal lands. Jatropha can also improve soil quality because of its deep root system. Jatropha is highly suitable for small-scale production because its seeds can be stored before processing. However, biodiesel production is costly, and this favours outgrowers' schemes in which producers deliver to local processing plants. Moreover, the crop is still largely undeveloped and economic profitability of biodiesel from Jatropha would require intensive crop management which could result in competition for top farm land.

- Dedicated energy crops (e.g. poplar, willows, alfalfa, switchgrass, miscanthus or even wood or crop residues) offer much greater promise as feedstocks, especially for second-generation biofuels currently under development. However, these second-generation feedstocks have yet to be fully commercialized, and the dates for doing so have been pushed back many times. Though research and development programmes have progressed in many advanced economies, the key obstacle to full commercialization continues to be high capital investments and the lack of cost competitiveness compared with some of the most efficient first-generation feedstocks (e.g. sugar cane, palm oil).

Overall, most biofuel production still depends on a few crops (e.g. maize, rapeseed), driven largely by government support, including subsidies and mandates, especially in the USA and the EU. Many attractive feedstocks that compete directly with food crops (e.g. Jatropha, sweet sorghum) remain at early development stages. The concern over drawing land use away from food production may favour using agricultural residues as feedstocks for second-generation biofuels instead of using dedicated energy crops which require new crop lands. However, dedicated energy crops may offer higher biomass productivity per unit of land. The large biomass demand for a commercial second-generation biofuel plant requires complex logistics systems and good infrastructure to provide biomass at economically competitive costs. This is a particular challenge in the rural areas of the studied countries, where poor infrastructure, complex land property structure and the predominance of small land holdings increase the complexity of feedstock logistics (e.g. in Cameroon, India, South Africa and Tanzania).

Even when second-generation biofuels become a commercial reality, there may still be concern about competition for food-crop land. While many feedstocks are touted as adaptable to marginal land conditions, the economics of the biofuel industry are such that these feedstocks would only take off under intensive production practices, occupying fertile lands and potentially crowding out food crops. Development of these feedstocks in more marginal areas by small-scale farmers is less likely without government incentives. However, financing commercial second-generation biofuel plants should not be a problem in most of the studied countries (e.g. Brazil, China, India, Mexico, South Africa and Thailand), since foreign direct investment could be used in addition to domestic funding.

The review in this chapter is by no means exhaustive. Many more countries (e.g. Colombia and Uruguay) have the potential to develop significant biodiesel production and exports given their available land and socio-economic conditions. Similarly, Central and Eastern European countries may become important biofuel or feedstock suppliers for the Western European countries. Also, many Southern African economies could offer good prospects for sweet sorghum, even when assuming a low level of inputs. Many developing countries (especially populous ones) have determined to not use food crops for biofuels. This is especially the case in China and India, which target non-food feedstocks in promoting the biofuels industry, and they already account for a considerable part of the global production.

In the absence of consistent government support to biofuels, concerns over economic viability and long-term security on invstments may have largely impacted the slow pace of biofuel spread, especially in developing countries. Even when economic viability can be established, biofuel investments could be jeopardized if social and environmental impacts are not also considered. Chapter 2 offers a full treatment of the sustainability of biofuels along its three key pillars: economic, social and environmental. Chapter 3 looks at certification and standards as an attempt to achieve sustainable biofuels development.

Chapter 2

Biomass and biofuel sustainability: An overview of issues, methods, and initiatives

2.1 Definition of sustainable development

The simplest definition of sustainable development was given by the World Commission on Environment and Development (WCED, 1987): "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." In the bioenergy sector, sustainability is a sine qua non for long-term viability for the following reasons:

- biofuels are promoted as part of renewable energy precisely to put human society on a sustainable path with respect to energy use as opposed to the continuous dependence on finite and exhaustible fossil energy;
- biofuels are aimed at lowering GHG emissions, rendering climate change conditions (i.e. rising average atmospheric temperature) more hospitable to human life in the long run;
- the potentially large share of land, labour and resources required for biomass production may overwhelm what is currently used for food and feed production, and hence jeopardize the long-term capacity to meet food and energy needs, even as biofuels could satisfy only 5 to 10 percent of total or global energy demand.

Tackling bioenergy sustainability requires dealing simultaneously with its many dimensions – economic, environmental and social. The latter dimension encompasses such considerations as social and gender equity, participation and equal rights (Jabareen, 2008). Moreover, social rights and resource stewardship are often linked. For example, it has long been recognized, notably by the International Union for the Conservation of Nature (IUCN), that the conservation of ecosystems is best served when the interests of the rural communities who use them are fully taken into consideration. Likewise, environmental and economic interests are best preserved if social interests are also considered. Thus, the socio-institutional, economic and environmental dimensions are or can be seen as complementary and not unrelated or contradictory (Jabareen, 2008).

As will be seen in Chapter 3, many governments, non-governmental organizations (NGOs), and, increasingly, the private sector subscribe to the view of the need for sustainable development of biofuels. This chapter examines different factors governing the sustainability of biomass production for biofuels that have been identified as particularly important. First, biofuel investments with a long-term perspective must pass the economic sustainability test, which assesses: when production makes sense from an economic point of view; which stable competitive conditions would induce producers to opt for biofuels production; what impacts increased production may have on competing uses for the feedstock (primarily food and feed); and to what extent biofuels can be a reliable substitute for fossil fuels. The second test is the environmental sustainability, which includes addressing criteria such as GHG emissions, soil stress and its ability to maintain productive capacity, available water resources, air and water pollution and biodiversity. Third, social sustainability encompasses considerations of rural development, gender mainstreaming, community involvement, inclusiveness of small farmers in the production processes, labour and land rights. In this chapter, we will examine how these various dimensions of sustainability relate to biofuel development; address sustainability assessment methods; and provide an overview of some of the main sustainability initiatives to date.

A discussion of sustainability inevitably leads to the notions of standards, criteria and indicators, and these require short explanations before we embark on the core topic of the chapter.

In this report, we define a **standard** as a rule for the measure of value or quality that ensures desirable characteristics of products and services – such as environmental friendliness, safety, reliability, efficiency and interchangeability – and at an economical cost. Standards have the following roles: they make the manufacturing and supply of products and services more efficient, safer and cleaner; they safeguard consumers; they provide governments with a technical and scientific basis for health, safety and environmental legislation; they make trade between countries fairer by creating a level playing field for all competitors in a particular market; and for developing countries, they represent an international consensus on the state-of-the-art, enabling them to take the right decisions when investing scarce resources. Dankers (2003) defined a standard as a set of principles and criteria aiming to guarantee that products and production processes were acceptable.

A **criterion** is a measurable quality characteristic to which a standard conforms, while an **indicator** is a measurement or parameter that determines whether or not the criterion has been met. For example, if soil conservation is set as a standard, a criterion will be soil erosion and the indicator will be T-threshold level: the measurable level of soil erosion above which the production process is unacceptable from the perspective of soil conservation.

Sustainability or the absence of it, even in a localized context, has a global impact and it is a challenge to clearly establish limits as to what is and what is not sustainable. Since consensus is almost impossible to achieve, there have been many initiatives and endless debates in a number of international fora about sustainability, its criteria and indicators. Table 2.1 summarizes the main initiatives on biofuels and biomass sustainability discussed in this section.

We will cover successively economic, environmental and social sustainability dimensions in the context of biomass and biofuel production, trade and use.

2.2 Economic sustainability of biomass

Three of the most important criteria for economic sustainability are profitability (the price of the biofuel exceeds the production costs), efficiency (the maximum amount of yield is obtained with a given quantity of resources) and equity (distribution of benefits or value added among actors along a biomass-biofuel value chain or across generations). The imperative of sustainability requires that we clearly consider these criteria in both the short and long term. Hence, from the perspective of sustainability, the first objective is to ensure the long-term economic viability of the productive system.

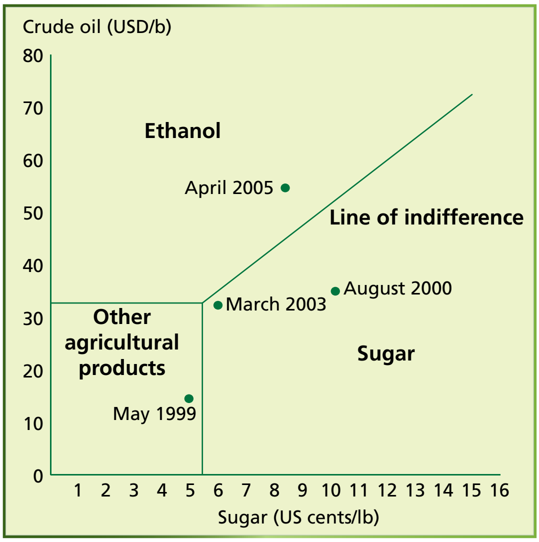
2.2.1 Profitability and efficiency

The first criterion for long-term viability of a production system utilizing resources to produce a marketable output is that it shows economic profitability: producers will only be willing to pursue biofuel production if it is economically profitable. Key factors that can affect profitability include alternative competitive uses of the feedstocks and energy prices. Alternative uses of the feedstock play an important role in the decision making process of producers. If prices for biofuels fall below the prices of other possible end-products (food, feed, timber, etc.) it would be more profitable to cultivate these products than to derive fuel out of the feedstock. Accordingly, their prices determine the price floor for biofuels. To be profitable and competitive with fossil fuels, biofuel production costs have to stay below the price of the oil equivalent. Therefore, oil prices set a price ceiling for the price of biofuels. If costs exceed this value, the biofuels will be automatically priced out of the market (Schmidhuber, 2007).

This link can be shown graphically. Nitsch and Giersdorf (2005) depict the relationship between the Brazilian sugar and ethanol markets (see Figure 2.1). The production of sugar is commercially feasible as long as the production costs are covered. Nevertheless, when oil prices rise and sugar prices fall, ethanol may be the more efficient choice. The line of indifference shows the parity price of ethanol – the circumstances in which farmers will be indifferent to producing ethanol or sugar. Also, a situation where both oil and sugar prices remain low at the same the time is quite possible, as was the case in May 1999, when neither ethanol nor sugar production was breaking even. Hence, the farmers would have been better off producing another feedstock. Figure 2.1 makes clear that the costs of biofuel production are relative. For example, in 2000 when sugar prices reached almost USD 0.24 per kg, the opportunity costs of producing ethanol made it cheaper for Brazil to import ethanol from the United States, in spite of the absolute cost advantage of Brazilian ethanol production (Gallagher et al., 2006).

Although new innovations have enabled more flexibility to react to market signals, a wide number of factors still limit the flexibility of the market participants. For example, there is no perfect substitution of biofuels for fossil fuels, since vehicles, factories and fuel stations are subject to certain technologies.

FIGURE 2. 1 - LINKAGE BETWEEN THE BRAZILIAN ENERGY AND SUGAR MARKETS



Source: After Nitsch and Giersdorf, 2005, with slight modifications

Another key factor that makes this economic assessment less clear-cut is the prevalence of subsidies that sustain the biofuel production in most producing countries, especially in industrialized economies. The economic profitability of biofuels has been invariably attributed to government subsidies or mandates, the only exception being Brazil's sugar cane ethanol. Some argue that biofuels, by pushing prices up through increased demand, could lower the very need for farm subsidies. The problem thus far is that most biofuel programmes in advanced economies are themselves maintained largely through government subsidies and demand-generating mandates.

In recent years, biofuel subsidies have been monitored under the Global Subsidies Initiative (GSI) by the International Institute of Sustainable Development (Steenblik, 2007) and by the International Energy Agency. According to the International Energy Agency, estimates for global renewable subsidies for biofuels reached USD 22 billion in 2010, 6 percent higher than in 2009, mostly in the form of tax credits for investment or production or premiums over market prices to cover the higher production costs compared with traditional fuels. Out of that total, the EU and Member States are estimated to spend approximately €3.1 billion on biofuel subsidies, while the total for the USA was USD 6 billion in 2010.

According to a study by the Global Subsidies Initiative, the authors concluded that government subsidies tend to promote feedstocks that, in their own right, are not the most efficient and profitable in the long run (Steenblik, 2007). The study also drew conclusions for several of the countries analysed. For Australia, the same study revealed that while biofuels can provide some benefits through the displacement of petroleum and fossil fuels and, under certain conditions, through reducing GHG emissions, these gains are relatively small in comparison with their subsidy cost. The study recommended that national blending mandates for biofuels be preceded by a thorough examination of the costs and benefits. In the case of China, subsidies for growing biofuel feedstocks on marginal land turned out to be higher than subsidies for setting aside such land for environmental purposes, thus encouraging cultivation of conservation areas.

For Canada, the same GSI study found that mandates for the use of renewable fuels at the national and provincial levels ensured that biofuels will be sold even when they are more expensive than gasoline or diesel, their principal competitors, providing a guaranteed source of demand, regardless of the cost of production. It was concluded that subsidies to Canadian biofuels were an expensive way to conserve fossil fuels or reduce GHG emissions, and tradeoffs with respect to GHG reductions appeared even less attractive. Subsidizing corn or wheat ethanol or canola biodiesel with taxpayers' money removed only one tonne of CO_2-equivalent, rather than up to 100 tonnes by purchasing emission reductions on the market. While many programmes provided larger incentives for smaller agricultural producers, such policies prevented the industry from making use of economies of scale to improve efficiency, thereby fostering subsidy dependence.

In the case of the EU, it was evident that while biofuels did displace some petroleum and fossil fuels, and reduce some GHG emissions, the cost of obtaining a unit of CO_2-equivalent reduction through biofuel subsidies was very high. Even under the best-case scenario assumptions for GHG reductions from biofuels, governments could achieve far greater reductions for the same amount of public funds by simply purchasing the reductions in the marketplace.

As for Indonesia, the conclusion from the same study was that replacing fossil fuels by subsidizing biofuels, a more expensive alternative than their fossil equivalents, made no economic sense. The funding liberated by biofuel subsidy reform could be directed to helping those most in need, through social protection measures targeting the poor, including a payment mechanism that allows recipients to spend on other choices such as food, health care or education. Similarly, for Malaysia it was recommended that the government refrain from intervening in the market for biofuels through such measures as direct price support or imposing mandatory blending.

Even in the United States, the design of subsidy programmes for biofuels failed to take into account the environmental effects of particular biomass production cycles. Still, the presence of a corn ethanol subsidy over a 30-year period seems to have shielded the US corn ethanol industry enough to mature and gain international market share. Up until the end of 2011, the USA maintained a subsidy for corn ethanol (45 cents per gallon given to refiners to blend ethanol gasoline with ethanol) coupled with a tariff on imported ethanol at 54 cents per gallon. Together, these two measures effectively cut 99 cents from the price of every gallon of ethanol produced, making American corn ethanol far more cost-effective than competitors from other countries – or other crops. Starting in 2012, both the ethanol subsidy and the tariff were terminated; however, this occurred at a time when the USA had already become a major exporter of ethanol, shooting past Brazil as the latter experienced faster growth in domestic ethanol demand than in ethanol supply growth.

According to the International Energy Agency, the cumulative cost of biofuels between 2011 and 2035 is expected to total USD 1.4 trillion to meet mandates for blending and other biofuel targets and to cover tax credits to the industry. Except in Brazil, biofuels are not cost-competitive with oil-based conventional fuels, and subsidies are required to meet the mandated targets. However, these projections were made based on the assumption of a continued US ethanol subsidy which, in fact, expired at the end of 2011.

It is difficult to assess the economic competitiveness of the various biomass-biofuel combinations in the presence of subsidies and mandates, but another way to assess economic viability is through development of production cost data.

A compilation of costs between feedstock and countries is shown in Table 2.1.

In general, feedstock costs account for the main part of the production costs, while by-products can increase the economic viability of biofuel production. Two exceptions to this general pattern are ethanol derived from sugar cane in Brazil and from sugar beet in the EU.

Estimated biofuel production costs show significant differences depending on factors such as scale of the plant, technology complexity, energy sources and feedstock costs. Little detailed data on advanced biofuel production costs are available, because there is as yet no experience from large commercial-scale production plants. Long-term production cost estimates, to 2020-30, are based on the lowest fixed and variable costs of fuels that might be achieved. In the end, learning rates and cumulative production will determine when "long-term" costs are achieved.

Comparing total production costs of the different biofuel-country combinations in Table 2.1, rapeseed-based biodiesel in the EU is shown to be the most expensive (USD 3.29 per gallon) while sugar cane-derived ethanol in Brazil is the cheapest (at USD 0.25 per litre).

Economic profitability also depends on efficient use of by-products and the

TABLE 2.1 - COST OF PRODUCTION OF BIOFUELS FROM SELECTED FEEDSTOCKS (VARIOUS SOURCES, YEARS)

Biofuel/ Country	Feedstock	Feedstock (percent of total)	Total Production Costs ($/l)
Biodiesel			
USA	Soybean oil	80-85	0.64
Malaysia	Palm oil	80-85	0.52
EU	Rapeseed	80-85	0.84
India	Jatropha	80-85	0.51
Diesel			
USA	Diesel	75	0.38
Ethanol			
USA	Corn	39-50	0.38
USA	Cellulosic sources	90	0.69
Brazil	Sugarcane	37	0.25
EU	Wheat	68	0.57
EU	Sugarbeet	34	0.74
Gasoline			
USA	Gasoline	73	0.33

availability of markets for them. Glycerine, for instance, is a significant biodiesel by-product in search of market uses. New biodiesel production technology may lead to an alternative chemical pathway that produces biodiesel without glycerine or by transforming glycerine into propylene glycol, which is used in manufacturing antifreeze.

Making use of co-products such as DDGS (Dried Distillers Grains with Solubles), a co-product of the ethanol production process and a high nutrient feed valued by the livestock industry, glycerine, bagasse, lignin or waste heat can reduce biofuel production costs by up to 20 percent depending on the fuel type and use of co-product. In some cases (e.g. soy biodiesel), the biofuel is a by-product rather than the main product.

Recycled fats and oils are less expensive feedstock than virgin oils: for instance, historic prices for yellow grease are about half of soybean oil prices. However, the amount required to produce a gallon of biodiesel is slightly higher. Furthermore, animal fats such as beef tallow are less uniform than processed vegetable oils and require more processing to produce a uniform biodiesel product.

Overall economic profitability, and hence long-term viability for biofuels, is a moving target. It depends on cost-reducing technological improvements and relative price competitiveness (with alternative uses of feedstocks). Competition with alternative uses of feedstocks may also be localized and highly determined by the presence or absence of policy incentives or disincentives.

2.2.2 Economic equity

The concept of intra-generational equity, referring to fairness in allocation of resources between simultaneous competing interests, has received relatively less attention than inter-generational equity (between present and future generations). It implies social and economic justice, quality of life, democracy, public participation and empowerment; the incidence and magnitude of unsustainable practices originate from power inequality. It is in this context that the environmental limits of supporting ecosystems are defined (Jabareen, 2008).

The growing global demand for liquid biofuels and the attendant environmental and socio-economic transformations might have different impacts on men and women in the same household as well as male- and female-headed households, as regards their access to and control of land and other productive assets, their level of participation in decision-making, employment opportunities and conditions, and their food security. Both the nature and the magnitude of these impacts will depend on the specific technology and on the socio-economic and policy context.

The potential high land-use requirement for biofuels might put pressure on the so-called "marginal" lands (perceived as less critical for food production), prompting their conversion to biofuels production.

The government of India, for instance, through its National Mission on Biofuels, aimed to bring around 400 000 hectares of marginal lands under cultivation of non-edible oil seed crops (mostly Jatropha) for biodiesel production. However, the majority of these lands, classified as common property resources (CPRs) in India, provide key subsistence functions and represent an integral part of the livelihood of the rural poor, supplying food, fodder, fuelwood and building materials. They contribute between 12 percent and 25 percent of the income to poor households. Similarly, in several sub-Saharan African countries, women are often allocated low quality lands by their husbands. The conversion of these lands to biofuel plantations might cause the partial or total displacement of women's agricultural activities, with negative repercussions for women's ability to meet household obligations, including traditional food provision and food security (Rossi, 2008).

2.2.3 Competition with food

One of the key drivers determining long-term economic viability of biofuels is competition with food. This is because biofuel production (through the use of biomass) may compete with food for the same resources, notably land, labour and water. Food security is a key developmental goal and the potential conflict with energy security can play out at many levels including national and even regional. Which takes priority and to what extent food security could impede large-scale biofuel development depend on the overall balance between size of population, projected growth, availability of land (or its scarcity) as well as its suitability for food crops versus energy crops only. Other contributing factors include prospects for increased productivity and the implications for land availability to meet multiple demands, as well as the relative profitability of feedstock for biofuels versus alternative uses of land, water and labour – for food, feed or other industrial uses. In the end, incentives for feedstocks for bioenergy versus food or other crop uses will boil down to which end-product offers greater value added and raises the incomes of farmers, who can then afford greater access to food and nutrition.

According to FAO's definition, food security exists when "all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food which meets their dietary needs and food preferences for an active and healthy life" (FAO, 2003, p.29). In other words, people obtain food security when there is adequate food available, supply is sufficiently stable, and everyone has access to the food (FAO, 2003). When feedstocks are used for food, the availability of food will be constrained by the biofuel supply as long as they compete for the same resources (land, fertilizers, water, etc.). The impact can be more or less direct depending on the feedstock and where it is cultivated. There are also indirect effects such as in the case of US maize for ethanol. Here effects on food security are channelled indirectly via world agricultural prices of grain and other food products whose supply and demand balances are affected by rising use of US maize in bioethanol. There are also non-food feedstocks, most notably Jatropha, under consideration to produce biodiesel; here the feedstock is inedible and does not require a lot of input.

In many parts of the world however, access is a more critical problem than availability *per se*. Increased use of bioenergy tends to push up food prices, especially if food or feed crops are used for energy. The impact of biofuel-induced price increases will not be the same for consumers and producers. Moreover, these biofuel-induced price effects are stronger in developing countries as expenditures for food are proportionally much higher in many developing countries, and also because a large part of the population is involved in agricultural activities. Whether the net impact will be positive or negative will depend on the country, the region, and ultimately the household and individual position.

The price of food depends on the degree of processing. In developed countries crop price has very little impact on the end food price. In developing economies, because food is less processed, higher crop prices play a greater role in setting final food prices. A higher percentage of Gross Domestic Product (GDP) is used for food so it has a greater impact on living standards.

The biofuels industry could create and improve existing market mechanisms (e.g. physical infrastructure and agronomic capability) which could lead to more efficient agricultural production. Brazil, for example, has achieved significant improvements in sugar production and ethanol processing. Between 1975 and 2000, sugar cane yields in the São Paulo region rose by 33 percent, ethanol production per unit of sucrose rose by 14 percent, and the productivity of the fermentation process rose by 130 percent (IFPRI, 2006).

The by-products of biofuel production can be useful sources of food. As grain ethanol production continues to expand, the production of Dried Distillers Grains with Solubles (DDGS), is expected to grow to more than 12 million tonnes annually and may depress prices in the feed market (EIA, 2007).

Another potential problem for food security is the role that biofuels might play in destabilizing food supply, especially if agricultural prices become more linked to energy prices and hence rise and fall quickly. Certainly the trade-offs would have to be weighed between the positive benefits (energy security, climate change, high protein co-products, wealth generation) and inflationary problems.

Overall, competition with food is a potentially significant concern when investing in biofuels. The issue is not entirely resolved with second generation biofuels, even if they use non-food feedstocks because of indirect land-use changes and because of the potentially huge market demand for renewable energy in comparison to agriculture. Consequently, policies that introduce sustainability criteria and standards, if properly implemented, could contribute to mitigating this potential fuel vs food conflict.

2.2.4 Trade competition

Along with economic sustainability, equity of trade refers to the possibilities open to different countries for entering the international bioenergy market. Given the size of the energy market, future energy demand, the distribution of land resources and the environmental priorities, industrialized countries are expected to remain major consumers of biofuels while many developing countries have the potential to become main producers and exporters. But biofuel trade has been restricted in recent years by industrial countries through a combination of subsidies and tariffs to ensure that the support is directed towards domestic producers only (Kojima et al., 2007)[4]. Still, trade is expected to play a significant role in the global development of biofuels.

[4] In the US, corn ethanol has been subjet to a 45 cents per gallon tax credit for gasoline blenders coupled with 54 cents per gallon import tariff. This policy instrument, known as the Volumetric Ethanol Excise Tax Credit (VEETC) has been continued under the the American Jobs Creation Act of 2004 and the Renewable Fuels Reinvestment Act, RFRA, introduced in 2010 however both the tax credit and import tariffs were terminated starting in 2012. The European Union has preferential treatments for ethanol imports from many developing countries, but excludes potentially important exporters such as Brazil and Argentina. The EU has 102 EUR/m3 for denatured and 192 EUR/m3 for undenatured ethanol.

The international market for biofuels is expected to smooth out supply and demand imbalances between exporting countries – with abundant raw material resources and the potential for industrial development of the sector (e.g. Brazil, Indonesia) and/or tax incentives to export products (like the USA) – and importing countries that have regulatory targets for biofuels, but lack sufficient resources to achieve those targets (such as the USA and many European countries) - see chapter 1, section 1.2 for details on biofuel trade.

How trade regulations for biofuels will evolve in the future is an open question. There is an ongoing dispute in the World Trade Organization (WTO) about how bioenergy from biomass should be classified. While produced as agricultural commodity, the final product is used as an industrial substitute with the aim of improving the environment. As a result, bioenergy sources are treated differently in the Harmonized System; ethanol is considered an agricultural product, biodiesel a chemical product and wood pellets are part of wood wastes. This translates into different applications of tariffs and subsidies (where rules are stricter for industrial goods than for agricultural goods). Some countries (like Brazil) argue that liquid biofuels should be classified as environmental goods to facilitate tariff clearance (WTO, 2007). Moreover, there is also the problem of tariff escalation as processing increases. In the EU, the import tariff on crude palm oil is 3.8 percent, while refined palm oil is subject to a tariff of 9 percent and stearine from Malaysia and Indonesia to 10.9 percent (Kaditi, 2008).

The growth of biofuel production and trade are ultimately interlinked. The potential for biofuel demand growth is huge for much of the world, especially industrialized and large emerging economies, but the inherent imbalances between supply possibilities and demand are also significant. This gives trade a critical role in regulating supply and demand balances globally and between countries with excess production and excess demand.

Overall, a larger growth in biofuel trade could cut both ways. On the up side, trade will offer new and significant development opportunities and new sources of revenues for producers, including small-scale farmers. On the down side, expanding trade in biofuel could unleash huge investments in biofuels in some areas with unintended consequences (e.g. overuse of land and water resources) if sustainability safeguards are not maintained. Appropriate trade and development policies must ensure a more balanced outcome from these development strategies. Modalities for such policies can only be specified at a country or even subnational level.

2.2.5 Economic sustainability assessments

Cost-benefits analyses (CBA)

Cost-benefit analysis (CBA) is a standard economic tool applied to evaluate a project's financial and economic profitability, a prerequisite for its viability. Typically, in CBA, a net present value (NPV) is calculated, taking into account the expected in- and out-flows and factors such as time and risk preferences of affected stakeholders. If the NPV is positive, the project should be carried out unless capital is a significant constraint. CBA is a useful tool to estimate direct values of a project, but it requires that all costs and benefits are expressed in monetary terms. For intangible impacts, or products that are currently not traded on the market (health, risk, access to markets etc), methods based on revealed preferences or stated preferences can be applied (e.g. by taking expenditures for safety equipments as proxy for the value of a "bad" such as air pollution, or by asking stakeholders about their willingness to pay for a certain "good" like electricity).

For the specific case of biofuels, CBA differs from straight financial or commercial calculation in that it also attempts to quantify cost and benefits that do not necessarily have a market price. These are often called external costs or external benefits, and in this case, the relevant ones are:

- environmental benefits;
- employment benefits;
- security of supply benefits.

Environmental benefits of the various biofuel types and their alternatives have been estimated largely through the quantification of their life cycle GHG emission values, which is driven principally by the "price of carbon," given that it would be inappropriate to attribute a higher benefit than the cost at which similar reductions in emission gases can be achieved.

Cost benefit analysis requires making forecasts of the future. The decisions taken with respect to biofuels will have an economic and financial impact for many years to come, and will involve costs and generate benefits, year after year. For this reason decision makers have to know the anticipated consequences of the alternatives they consider.

Full-cost pricing

Pricing policies are a central element in the transition towards a greener economy. Full-cost pricing means that the price of a transaction not only reflects information about its individual costs and benefits, but also about the external cost it imposes on society through environmental damages. Pricing is particularly promising in the area of climate change, where instruments can effectively and efficiently reduce carbon emissions. But the application of full-cost pricing goes well beyond carbon and may cover areas such as local pollution, waste, agriculture and fishery.

Full-cost pricing also calls for phasing out harmful subsidies. Today, many countries use subsidies on fossil fuels and agriculture to give poor households access to basic needs or to shield certain sectors from competition in order to protect existing jobs. However, subsidies are often ineffective, inefficient, and lead to underpricing of damaging activities. Their phase-out is essential for the transition towards a greener economy.

Some developed countries have introduced or proposed explicit carbon pricing policies. For example, the Scandinavian countries, the United Kingdom and the Netherlands have introduced explicit carbon taxes. However, carbon taxes in these countries generally exempt large emitters. In 2005, the EU introduced an emission trading scheme (ETS) for large carbon emitters. The trade price has fluctuated substantially over the years. Today, the EU-ETS covers less than half of all carbon emissions in Europe. The majority of permits are grandfathered on the basis of previous emissions. Estimates suggest that governments thus forgo between 0.3 and 0.6 percent of GDP in revenue.

In case of cross-border problems such as climate change, international cooperation is necessary to obtain an efficient pricing policy. The social damage from carbon emissions must be the same, wherever in the world they arise, and from the perspective of efficiency, this also requires that marginal abatement costs are also the same. This calls for identical carbon prices. If this is not feasible, countries may commit to a minimum carbon price, to be imposed by either a carbon tax or a cap-and-trade system. Incomplete participation could cause significant economic inefficiencies as mitigation costs differ markedly across countries, implying substantial gains from trade. If carbon is priced only by a subset of countries, this induces carbon leakage: a shifting of emissions to non-participants. Moreover, to the extent that carbon pricing by a subset of countries reduces the world price of fossil fuels, this would increase emissions by non-participants. International cooperation is therefore necessary to ensure effective achievement of a greener economy at minimal cost. International transfers may be necessary in order to sustain such cooperation and to include less developed countries in the agreements. Indeed, the fastest growth of carbon emissions in the coming decades will come from emerging and developing countries.

2.3 Environmental sustainability of biomass-biofuels

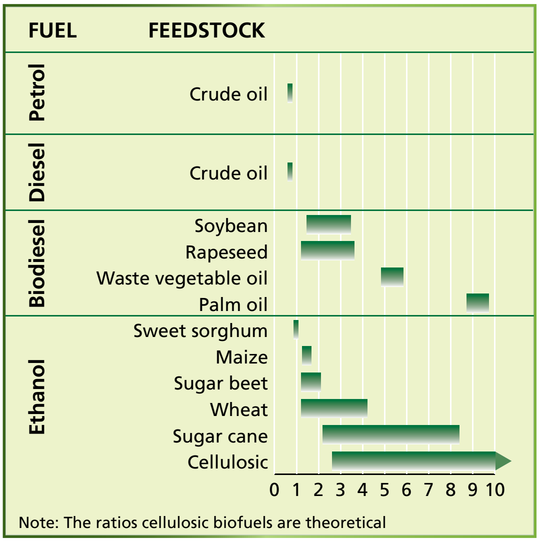
2.3.1 Energy balance

One important motivation for bioenergy policies is to increase energy security. Fossil fuels are finite and prices are expected to rise substantially in the future. Renewable bioenergy is seen as a way to diversify the energy sources.

The contribution of any biofuel to energy supply depends both on the energy content of the biofuel and on the fossil energy going into its production. This includes energy required to cultivate (fertilizers, pesticides, irrigation technology, tillage) and harvest the feedstock, to process the feedstock into biofuel, and to transport the feedstock and the resulting biofuel through the various phases of production and distribution.

Fossil energy balance, defined as the ratio between renewable energy output of the resultant biofuel and fossil energy input needed in its production, is a crucial factor in judging the desirability of biomass-derived biofuel: this concept measures to what extent biomass is qualified to replace fossil fuels. Figure 2.2 shows reported theoretical ranges of fossil energy balances of liquid biofuels according to fuel and feedstock. An energy balance of 1.0 indicates that the energy requirement for the bioenergy production is equal to the energy it contains (Armstrong et al., 2002). In other words, the biofuel provides no net energy gain

FIGURE 2.2 - FOSSIL ENERGY BALANCES FOR LIQUID BIOFUELS



Source: Retrieved from FAO (2008a, p.17)

or loss. A fossil fuel energy balance of 2.0 means that a litre of biofuel contains twice the amount of energy as was required for its production.

Variations in the estimated fossil energy balances across feedstocks and fuels depend on factors such as feedstock productivity, production location, agricultural practices and conversion technologies, including the source of energy used for the conversion process.

Conventional petrol and diesel usually have an energy balance ranging between 0.8-0.9 because some energy is consumed in refining crude oil into usable fuel and transporting it to markets. If a biofuel has a fossil energy balance exceeding these numbers, it contributes to reducing dependence on fossil fuels.

For crop-based ethanol, the estimated balances range from 1.34 for maize to around 2–8 for sugar cane[5] . Put differently, corn ethanol yields 34 percent more energy

[5] Excluding indirect land use change effects.

than it takes to produce it, including growing the corn, harvesting it, transporting it, and distilling it into ethanol, given the following assumptions: fertilizers are produced by modern processing plants; corn is converted in modern ethanol facilities; and farmers achieve average corn yields. It is to be expected that the Net Energy Balance value will rise with increases in corn yield. A higher net energy balance could be due to a higher average corn yield that lowered the energy input used per acre, increased energy efficiency in fertilizer production and other agricultural chemicals, the adoption of energy-saving technologies in corn ethanol conversion, and higher co-product credits (Shapouri et al., 2002).

Ethanol from sugar cane may have the highest energy balance, but it displays considerable variation from 2 to 8. As mentioned in Chapter 1, the best results are achieved in Brazil because feedstock productivity (biomass yield per ha) is the highest and the use of bagasse (biomass residues from sugar cane) for power and heat generation is very efficient.

It is generally acknowledged that biodiesel produced from temperate oilseeds, sugar beet, wheat and maize have limited ability to displace other fuels either because of their low yields or their high input requirements. Estimated fossil fuel balances for biodiesel range from around 1 to 4 for rapeseed and soybean feedstocks, due to the lower biomass yields per ha and the more energy-intense conversion process. Palm oil could reach an energy balance even higher than 9.0 (i.e. nine times the energy required for its production).

Conventional biofuels are relatively mature, but overall sustainability of the technologies could be further improved. Conversion efficiency improvements will not only lead to better economic outcomes but also increase land-use efficiency and the environmental performance of conventional biofuels.

For conventional biodiesel, key areas for improvement include:

- more efficient catalyst recovery;
- improved purification of the co-product glycerine;
- enhanced feedstock flexibility.

For conventional ethanol, key areas for improvement include:

- new, more efficient enzymes;
- improvement of the nutritional value of DDGS;
- better energy efficiency, which can raise the conversion efficiency and reduce production costs.

Further cost improvements could be achieved by maximizing value-added co-product solutions, and by better integrating upstream and downstream processes. Producing conventional and/or advanced biofuels in biorefineries would promote more efficient use of biomass and bring associated cost and environmental benefits.[6]

Generating ethanol from lignocellulosic wastes through hydrolysis and fermentation has the potential to give very encouraging bioenergy yields in relation to the required fossil energy inputs, but the technology has yet to be fully deployed commercially. The conversion of cellulose to ethanol involves two steps: the cellulose and hemicellulose components of the biomass are first broken down into sugars, which are then fermented to obtain ethanol. The very wide range of estimated fossil fuel balances for cellulosic feedstocks reflects the uncertainty regarding this technology and the diversity of potential feedstocks and production systems.

[6] Milestones for technology improvements. International Energy Agency. 2010.

2.3.2 Greenhouse gas and other air pollutants

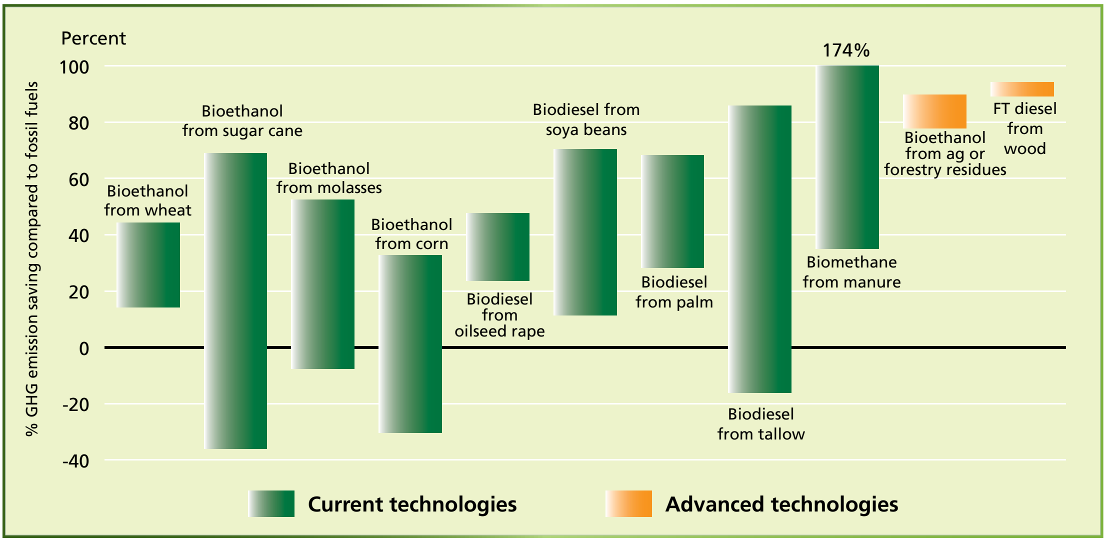
Tackling global warming and the possibility of reducing greenhouse gas (GHG) emissions is the second main driver for biofuel development. The negative effects of GHG emissions on climate have been known for a long time. The Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, 2007) observed that GHG emissions need to be reduced by 50-85 percent by 2050 in order to stabilize the concentration of GHGs in the atmosphere. Given that fossil fuels used in transport and heating and cooling systems are the largest contributors to global warming (about 75 percent of total CO_2 emissions), one of the most important targets will be to cut emissions in this area. GHG emission assessments typically include those of CO_2, methane (CH_4), nitrous oxide (N_2O) and halocarbons. The gases are released during the whole-product life-cycle of the biofuel depending on the agricultural practices (including fertilizer use, pesticides, harvesting, etc.), the conversion and distribution process, and the final consumption and use of by-products.

Concerns about climate change and the need to reduce GHG emissions have become increasingly important in continuing policy support for biofuels. The biofuel industry is therefore increasingly required to demonstrate that the net effect is lower GHGs when taken across the whole lifecycle, from crops to cars. While plants absorb CO_2 from the atmosphere when they are growing, which can offset the CO_2 produced when fuel is burned, CO_2 is also emitted at other points in the process of producing biofuels. Figure 2.3 compares life-cycle GHG balances of different conventional and advanced biofuels.

Reducing the carbon intensity of the energy used by transport is one means of reducing transport's GHG emissions, which are largely carbon dioxide (CO_2). In the medium to long term, it is likely that the energy mix used in the transport sector will change significantly, so biofuels will be one of the solutions to decarbonize transport. At present they are the only commercially viable decarbonization option. Their competitiveness compared to other low(er)-carbon energy sources for transport such as natural gas, electricity or hydrogen also stems from the fact that no new distribution networks are needed and that conventional petrol or diesel engines can be fuelled with biofuels, at least up to a certain blend rate.

A critical and highly debated issue on how best to assess GHG emissions is the thorny question of land-use change and how to define its outer limit for purposes of measurement. Land-use change occurs when biofuel feedstock induces a relocation of food and fibre production, housing, and other uses to former grass- or woodlands. Land and plants sequester carbon. When land conversion takes place, CO_2 is released due to the decomposition of organic matter and practices such as burning to clear land. This may be a lengthy process stretching over decades. If grasslands or forests are converted into agricultural land to produce biomass, the GHG reduction potential will be different than if biomass production is just started from agricultural land. So far, studies on biomass and GHG emissions assume that land use remains unchanged. To calculate GHG emission balances, Fargione et al. (2008) defined carbon debt as the amount of CO_2 released within the first 50 years. If the bioenergy net GHG emissions are lower than the GHG life-cycle emissions of the fossil energy, the carbon debt will be reduced over the years. However, the problem is that we are racing against the clock as far as bringing climate change under control. So before the carbon debt is completely paid off, the influence on climate change can be stronger than fossil fuels if CO_2 release from biomass production is much higher initially from a "bad" land-use change scenario. Fargione et al. (2007) calculated that the carbon debt can be paid

FIGURE 2. 3 - LIFE-CYCLE GHG BALANCE OF DIFFERENT CONVENTIONAL AND ADVANCED BIOFUELS



Source: (IEA, 2011)

off in as little as 17 years for the wooded cerrado in Brazil and up to 423 years in the peatland forests of Indonesia and Malaysia (Figure 2.4). It is clear that the impacts of both direct and indirect land-use change should be assessed to get an adequate estimation of GHG emissions associated with biofuel production.

Air pollution is related to GHG emissions; its localized effects contribute to deteriorating local and regional air quality. During biomass production, the major air pollutants emitted include CO_2, N_2O, CH_4, carbon monoxide (CO) and nitrogen oxides (NO_x). Such gases and particles are released when burning practices are applied to clear the fields. Moreover, nitrogen fertilizers are one of the foremost emitters of N_2O, which, besides being a potent GHG, also causes ozone depletion, which itself contributes to climate change (Worldwatch Institute, 2007).

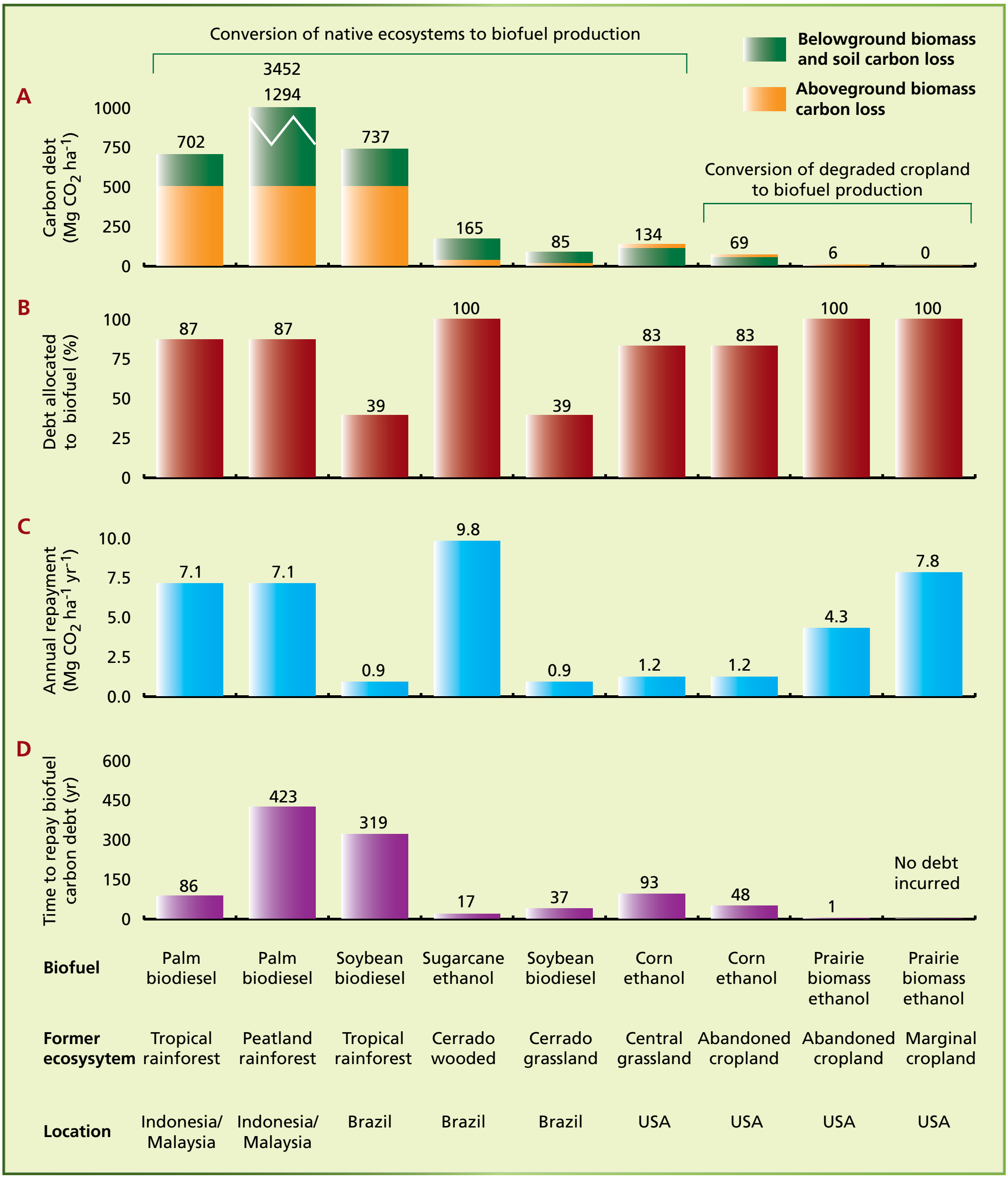
During biofuels use in transport, a number of pollutants are released, such as CO, particulate matter (PM), total hydrocarbons (THC), volatile organic compounds (VOC), sulphur compounds and dioxins. These gases can be dangerous both for the environment and human health. However, compared to fossil fuels, biodiesel and ethanol emit fewer pollutants, except for NO, which are higher under biofuels.

2.3.3 Life cycle assessments

In order to determine whether a biomass-biofuel system results in a net reduction in GHG emissions or an improved energy balance (input-output energy ratio), a Life-Cycle Assessment (LCA) is commonly used. According to ISO 14040, an LCA is a "compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle."

In an LCA, all input and output data in all phases of the product's life cycle including biomass production, feedstock storage, feedstock transportation, biofuel production, biofuel transportation and final use are required. Also, all outputs are accounted for including gases (leaked or captured) and by-products. Many LCA

FIGURE 2.4 - BIOFUEL CARBON DEBT ALLOCATION, ANNUAL CARBON REPAYMENT RATE (YEARS)



Source: Fargione et al. (2008, p.1236).

approaches are reported but most focus on a few key input categories and two primary environmental criteria: GHG emissions and energy balance. Few LCAs encompass additional criteria such as water use, or impacts on soils.

LCAs of the environmental impacts of biofuel production and consumption have shown a wide disparity in results, from net reduction in GHG emissions to a net increase, as well as risks of unintended negative environmental impacts, depending on the kind of feedstock used and how it is produced and processed. LCA analyses are challenging not only because they require large amounts of information, but also because they attempt to combine disparate quantities in ways that require considerable explanation and interpretation. For example, an LCA study may examine the energy consumption of a product and combine energy inputs as different as electricity produced by a nuclear power plant, heat provided locally by burning natural gas, and the power from a diesel fuel-powered truck which transports the product to market. Some energy sources, such as solar heat, are considered to be available at no cost and with no environmental impact

LCAs performed to date suffer from a serious lacuna: they seldom take account of indirect environmental impacts, such as GHG emissions as a result of vegetation cleared prior to growing the feedstock. Biodiesel is commonly considered to be "carbon neutral" because carbon released in burning the fuel is offset by growing the feedstock. However, where forest is converted to oil-palm plantations, the amount of GHG released may far outweigh any carbon emission reductions arising from the use of biofuels sourced from that land.

In a review of LCAs of liquid biofuel systems, Larson (2006) concluded that comparing LCAs is often difficult and displays a large variation in results, owing to different methodologies, system boundaries and input/output assumptions. Among the key points of discord between the different LCAs, Larson cites three sources: the inclusion of different GHGs; how to allocate co-product credits; and how to account for soil carbon.

For the first source (GHG types), Larson found that most LCAs cover emissions of CO_2, CH_4 and N2O when referring to GHG emissions. A few studies also included indirect gases such as nitrogen (NO_x), carbon monoxide (CO), and non-methane organic compounds (NMOC) that affect the ozone (O_3) (which in turn affects the climate). The same was true for aerosols like black carbon and sulphate. Yet, although these indirect gases could have a strong impact on global temperature, their estimation raises methodological difficulties and therefore they are often omitted from LCAs. N_2O, released from nitrogen fertilizers and leaf-litter decomposition, also presents another challenge. The impact of N_2O on the global surface temperature is approximately 300 times as large as CO_2. However, the estimation of the amount of N_2O released is often difficult since this is influenced by a large number of factors, namely soil quality, climate, annual/perennial crops, cultivation method, fertilizer and manure use.

The second source of discord between the LCAs is the assumption about the co-product credit allocation. As described in Chapter 1, the production of biofuels involves numerous co-products such as animal feed and bagasse. Markets already exist for many of these co-products (e.g. glycerine for pharmaceutical and personal care applications) or they can be used to power the production system. The challenge is how to allocate the calculated emissions between the main products and co-products. Methods can refer to weight, energy content and market value of co-products as well as the energy that would have been needed to produce other goods that the co-products replace. Inevitably, different assumptions can lead to very different results.

To account for soil carbon, it is necessary to measure how biomass stores soil carbon and to what extent this carbon can affect the LCA carbon balance outcome. Much depends on the type of feedstock analysed and prior land use types. Second generation energy crops characterized by high biomass yields like switchgrass and miscanthus cultivated on conventionally tilled soil induce an accumulation of soil carbon while the cultivation of these same crops on wood- or grasslands may reduce soil carbon. What further complicates carbon balance estimations is the slow process of carbon decomposition.

While the literature on LCA analysis for GHG emission and energy balance is growing, there is still no consensus on the ideal method. Pending such a consensus, the credibility of LCAs depends on a transparent description of the assumptions and on a sensitivity analysis of key parameters where uncertainty is significant.

The selection of different parameters can change the results. There is a nuance and variability of GHG balances due to the complexity of biomass energy systems (e.g. crop, region, energy carrier) and the sensitivity of a wide range of parameters. Some key methodological issues relate to calculation of GHG balance, including[7]:

- reference land-use (type, management system);
- indirect land-use;
- allocation;
- data input (specific data, default values);
- time scale issues; and
- uncertainties in methodology.

[7] Greenhouse Gas Calculation MethodsWorkshop. Sustainability certification for biofuels and bio-energy Brussels, January 29, 2009 Jinke va.n Dam Copernicus Institute - Utrecht University.

A series of initiatives by a number of international organizations is seeking to develop GHG calculation methodologies (Table 2.2).

2.3.4 An Example of Life Cycle Analysis: Sweet sorghum for bioethanol - credit versus allocation method

A study commissioned by FAO in 2009 focused on, among others, the energy and GHG impacts along the entire life-cycle of sweet sorghum for a number of production and use systems.In the fermentation process of the sweet sorghum grain, stillage is generated as a by-product, which can either be dried for direct use as feed, or concentrated and pelletized and thus converted into DDGS, also used as feed. Similarly, sweet sorghum leaves can either be left on the field as fertilizer or used as cattle feed in small-scale farming systems. In the latter case, wheat, as feed, is substituted by the leaves. To calculate the amount of wheat substituted, the energy content of both leaves and wheat is considered. The use of leaves as feed influences emissions due to transportation since a higher weight has to be transported. At the same time, to compensate for the higher nutrient removal from the field, a higher input of mineral fertilizer is necessary.

Also, surplus bioelectricity generated from sweet sorghum bagasse substitutes for electricity originating from different fossil energy carriers, such as hard coal and natural gas, with different associated credits for carbon dioxide emissions avoided. When the whole bagasse is converted into second-generation ethanol, the process energy for the first-generation ethanol conversion originates from external fossil energy.

The level of emissions is also influenced by mechanical versus manual harvest: while sweet sorghum is harvested mechanically in large-scale production systems, mechanization to separate the different crop

TABLE 2.2 - INITIATIVES TO DEVELOP GHG CALCULATION METHODOLOGIES

International Organizations	Initiatives
IPCC	(Guidelines for National Greenhouse Gas) Inventories for estimating national GHG inventories. UNFCCC - Specific methodologies developed for CDM projects.
Global Bioenergy Partnership (GBEP)	Task Force on the harmonization of methodologies for measuring GHG emission reductions from the use of biofuels. Development of a template + good practice guidance.
UNEP	• Two main review studies of LCA / GHG emissions of biofuels. • Identification research gaps and future recommendations.
IEA Task 38	Aims to demonstrate and promote the use of a standard GHG methodology.
Roundtable on Sustainable Biofuels (RSB)	• Draft standard on principles and criteria for sustainable biofuels: Principle 3 on GHG balances. • Aim: to establish an acceptable standard methodology for comparing GHG benefits of biofuels.

parts may be inadequate or unaffordable. In the case of manual harvest, only the diesel fuel for establishment is calculated while setting to zero the fuel used for harvesting (in contrast to sugar cane, Jatropha and cassava, sweet sorghum can be established from seeds, which allows for easy mechanization).

In the FAO study, two methods were cited to deal with the products and by-products being generated along the entire life-cycle, such as bagasse or stillage: *credit method* and *allocation method*.

In the *credit method*, credits are given to bioethanol for all by-products of bioethanol production. on the basis of their negating the environmental impacts of production of the conventionally produced goods that the by-products substitute. Examples are: stillage as well as vinasse as feed substituting for soy meal; DDGS in place of soy meal; and calcium carbonate as fertilizer instead of mineral fertilizer. By contrast, in the *allocation method*, all environmental impacts are assumed to be caused by the main product and the different by-products and thus allocated proportionately to both. Allocation calculations can be performed on the basis of: energy content (lower heating values) of the products and by-products; or of the masses.

Which of the two methodologies to use for dealing with the by-products significantly influences the GHG balance outcome: a saving of 5 tonnes of CO_2 equivalents by the allocation method and 10 tonnes of CO_2 equivalents, using the credit method. There is, as yet, no common agreement as to which of the two methods to use in life-cycle assessments. While the credit method reflects reality in much greater detail, inclusion of the diversity of uses of the by-products leads to wide variation in the results. In general, guidelines commonly refer to the allocation methodology since results come within a narrow bandwidth, and calculations are easier compared to the credit method. A comparison of the two methodologies is difficult, if not impossible, since the underlying questions and the associated system boundaries greatly influence the results and make comparison difficult if not impossible. For that matter, as a general conclusion, existing LCAs on bioenergy should be compared with great caution.

Accordingly, international guidelines and agreements – for instance ISO 14040 and 14044 as well as ISO 2006, the BIAS Framework and the Global Bioenergy Partnership – strive toward standardization and harmonization. In both methodologies, the juice and grains are used for ethanol production and part of the bagasse is used to generate process energy while the remaining bagasse can be used for allocation of co-product credits.

The FAO study has determined that, when applying the credit method, if sweet sorghum bioethanol is used instead of fossil fuel, credits and expenditures add up to a saving of about 10 tonnes of GHG (CO_2 equivalents) per ha per year. When producing first-generation bioethanol from 1 ha of land, 2 tonnes of CO_2 equivalents are emitted while 6 tonnes of CO_2 equivalents are credited for the use of by-products. By comparison, 6 tonnes of GHG are emitted through the production and use of the equivalent fossil fuel. Hence compared to fossil fuels, in general, first- and second-generation bioethanols from sweet sorghum hold considerable promise toward saving fossil energy carriers and GHG, thanks in particular to surplus bioelectricity when producing first-generation bioethanol, which more than compensates fossil energy expenditures for bioethanol production.

Given the significant potential for saving fossil energy and GHG emissions even when sweet sorghum grains are used as food instead of being processed into ethanol and the juice used to produce first-generation bioethanol, sweet sorghum presents itself as a highly suitable crop for reducing the competition between food and fuel. Higher biomass yields per ha due to optimized crop varieties and cultivation methods lead to higher GHG savings; the influence of higher juice and sugar yields is only minor. Also, the changeable nature of the carbon stock of the land used for sweet sorghum cultivation (land cover change) can significantly influence the GHG balance outcome. The higher the carbon stock in the natural vegetation in the cultivation area, the higher the carbon losses and lower the GHG savings; however, the GHG expenditures due to carbon losses are overcompensated by the ethanol production and credits for the use of by-products. An enormous potential for GHG savings is offered if sweet sorghum is cultivated on carbon-poor (degraded) soils. The GHG balance can also be increased significantly if the leaves are used as feed instead of being left on the field as fertilizer; however, there is a trade-off here in terms of soil organic matter depletion. The choice of harvesting methods, mechnical or manual harvesting, has only a very minor influence on the GHG balance outcome. Therefore, from a climate protection perspective, the choice between small- and large-scale production is immaterial.

As regards other environmental impacts (other than GHG emissions and fossil fuel depletion), the production and use of sweet sorghum bioethanol presents certain disadvantages in comparison to using equivalent amounts of fossil fuels: acidification of ecosystems due to acid rain/fallout; higher eutrophication impact (exclusively considering nutrient input from the air) due to, among others, ammonia emission from the use of mineral nitrogen fertilizer when growing the crop; ozone depletion; Photo Smog (creation of photo-oxidants such as ozone in air layers at ground level); higher risk of soil erosion during the early development stages; and soil compaction from heavy machinery in an intensive large-scale production system. At the same time, for some of these impacts, sweet sorghum's very ability to thrive under low-input conditions opens up the possibility to reduce the same.

2.3.5 Land use change (LUC)

The next key challenge facing LCAs is how to factor in land-use changes. A common method to estimate land-use change is to use remote-sensing images, especially for monitoring deforestation. On the basis of spatial patterns, different techniques are then used to identify the agents involved in the land-use change (dos Santos Silva et al., 2008). Further, the use of primary and secondary data on areas planted and harvested in the past can help predict future land-use patterns – even at the local level, if such data readings can be matched with other crops (Nassar et al., 2008).

There is a distinction between direct and indirect land-use change. When newly demanded products – such as biofuel feedstocks – are grown on converted land, this is described as direct land-use change (DLUC) and is typically included in the carbon accounting procedure in most life cycle analyses. Indirect land-use change refers to second, third and higher degrees of land substitutions. This is harder to measure and remains unresolved. There is currently a debate about measurement of GHG emissions resulting from indirect land-use change that may occur when increased demand for biofuel crops displaces other crops to new areas.

The indirect land-use change impacts (ILUCs) of biofuels describe the unintended consequences of releasing more carbon emissions because of land-use changes induced by the expansion of croplands for ethanol or biodiesel production in response to the increased global demand for biofuels. As farmers worldwide respond to higher crop prices in order to maintain the balance between global food supply and demand, pristine lands are cleared and converted to new cropland to replace the crops for feed and food that were diverted elsewhere to biofuels production. Because natural lands, such as rainforests and grasslands, store and sequester carbon in their soil and biomass as plants grow each year, clearance of wilderness for new farms in other regions or countries translates into a net increase in GHG emissions. Because of this change in the carbon stock of the soil and the biomass, ILUCs have consequences in the GHG balance of a biofuel.

Other authors have also argued that indirect land-use changes not only release sequestered carbon, but also produce other significant social and environmental impacts, putting pressure on biodiversity, soil, water quality, food prices and supply, concentration of land tenure, displacement of workers and local communities and cultural disruption.[8] Economic models (partial or general) are being used by some researchers to evaluate land demand on a global scale (Gnansounou et al., 2008).

2.3.6 Biodiversity

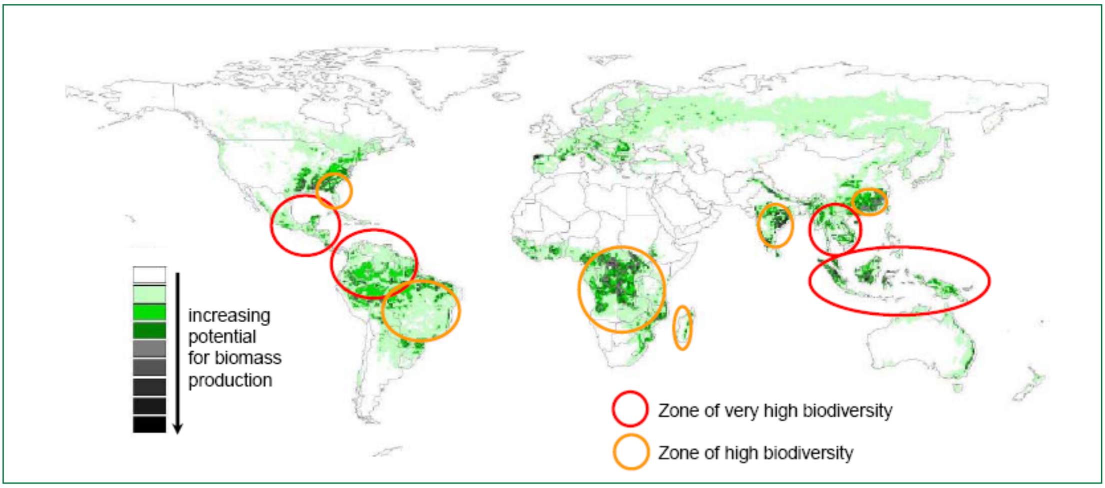
Biodiversity, defined as the abundance of species (plants, animals and micro-organisms) in a habitat, is essential for the performance of an eco-system. Biomass production for bioenergy can have both positive and negative impacts on biodiversity. When degraded land is used, the diversity of species might be enhanced. Yet, the practices of large energy crop monocultures can be detrimental to local biodiversity, especially through habitat loss, the expansion of invasive species and contamination from fertilizers and herbicides. Figure 2.5 shows conflict areas with high potential for biomass production as well as high biodiversity.

The reduction in global biodiversity has emerged as one of the greatest environmental threats of the 21st century. Urban and agricultural development have traditionally been the primary drivers of encroachment on important, biodiversity-sustaining ecosystems.

On a global scale, biodiversity is essential for the functioning of eco-systems which in turn ensure diverse gene pools and hydrological cycles which enable agriculture. However, on a field-scale, the most efficient cropping systems have great uniformity and very little biodiversity. The use of plant biomass to provide liquid fuels has the potential to increase agriculture's impact on biodiversity.

8 Timothy Searchinger, et al. (2008).

FIGURE 2.5 - CONFLICT ZONES: HIGH POTENTIALS FOR BIOMASS PRODUCTION VS. HIGH BIODIVERSITY



Source: IIASA, Kraxner 2007, Rokiyanskiy et al. 2006
Data from UNEP IMAPS

The extent of habitat loss depends on the type of land-use change. Many tropical countries have a good potential for biomass production given their favourable climatic conditions as well as their land and labour resources. Rising demand for biofuels increases the incentive to clear natural habitats such as tropical rainforests (UNEP, 2008). For instance, an expansion of soy plantations into the Amazon forest will cause a radical drop in biodiversity. By contrast, an area with a lower concentration of species will be less affected.

The problem of invasive species is tied to the introduction of non-native plants. African oil palm has proven to be invasive in Brazil as it spreads very well in wet regions. Other examples of feedstocks that have shown invasive tendencies are Jatropha[9] and castor beans (Howard and Ziller, 2008).

Water contamination with fertilizers and pesticides could also be a threat for biodiversity. Leakage of phosphorus and nitrogen into surrounding water can lead to a decrease in the variety of plants and animals, as well as an increase in unwanted algae (Sala et al., 2009). This is known as hypoxia, which means low oxygen, and is primarily a problem for estuaries and coastal waters. Hypoxic waters contain dissolved oxygen concentrations of less than 2-3 ppm. Hypoxia can be caused by a variety of factors, including excess nutrients, primarily nitrogen and phosphorus, and waterbody stratification due to saline or temperature gradients. These excess nutrients – eutrophication – promote algal growth. As dead algae decompose, oxygen is consumed in the process, resulting in low levels of oxygen in the water. Thus high-input managed biomass crops may bring negative impacts on biodiversity. Conversely, native and perennial crops that do not involve much input are likely to be less damaging, especially when crop-rotation is considered (Groom et al, 2008).

Policies to reduce environmentally harmful agricultural subsidies, or at

9 In the case of Jatropha, the Jatropha (genus) curcas (species) is not included in the Global Invasive Species Database. However Jatropha (genus) gossypiifolia (species) is included. Source: (http://www.issg.org/database/species/search.asp?sts=sss&st=sss&fr=1&sn=jatropha&rn=&hci=-1&ei=-1&lang=EN).

In developing countries, large amounts of total GHG emissions come from deforestation and forest degradation. Moreover, studies suggest that reducing emissions from deforestation in developing countries is a cost-effective option relative to GHG mitigation in other sectors with multiple benefits. Policy options and positive incentives are needed to reduce emissions from deforestation, as well as to enhance the uptake of CO_2 by forests.

2.3.7 Water use for agriculture (bioenergy) and water footprint

Water on the earth is 97 percent salt water and only 3 percent fresh water, of which slightly over two thirds is frozen in glaciers and polar ice caps. The remaining unfrozen fresh water is mainly found as groundwater, with only a small fraction present above ground or in the air. It is estimated that 69 percent of worldwide water use is for irrigation, with 15-35 percent of irrigation withdrawals being very unsustainable (WWF, 2010).[10]

Water resource management in agricultural systems and the concern for dwindling availability is obviously a local or even a regional issue; but the water challenge is oft-repeated in many regions of

[10] WWF Global Water report – fast facts 2010.

Box 2.1: European Union Renewable Energy Directive (RED) and its take on biodiversity

Under the Renewable Energy Directive (RED), the EU will not accept raw materials obtained from land with high biodiversity value, i.e. land that had one of the following statuses during or after January 2008:

(a) primary forest and other wooded land, that is to say forest and other wooded land of native species, where there are no clearly visible indications of human activities and the ecological processes are not significantly disturbed;

(b) areas designated by law or by the relevant competent authority for nature protection purposes;

(c) areas for the protection of rare, threatened or endangered ecosystems or species recognized by international agreements or included in lists drawn up by intergovernmental organizations or the International Union for the Conservation of Nature, subject to their recognition in accordance with the second subparagraph of Article 18(4); unless evidence is provided that the production of that raw material did not interfere with those nature protection purposes;

(d) highly biodiverse natural grassland, that is to say grassland that would remain grassland in the absence of human intervention and which maintains the natural species composition and ecological characteristics and processes;

(e) highly biodiverse non natural grassland, that is to say grassland that would cease to be grassland in the absence of human intervention and which is species-rich and not degraded, unless evidence is provided that the harvesting of the raw material is necessary to preserve its grassland status.

the world that it become a global concern (FAO, 2011a).

There are obvious potential environmental impacts associated with (over) extraction of fresh water, including salt water ingress into aquifers, ecological damage within surface water bodies, and habitat destruction. The possible social impacts include potential conflicts for water management among different users, reduced availability or quality of resources for municipal/domestic use.

In agriculture, crops that require less irrigation, fertilizer and pesticides, and that provide better year-round erosion protection will likely produce fewer negative water impacts. Understanding water quantity impacts depends on understanding the agricultural water cycle. Crops can be either rain-fed or irrigated. Irrigation water can come from groundwater or surface water; groundwater can either be withdrawn from a surficial aquifer (connected to the surface) or a confined aquifer.

Some of the applied water is incorporated into the crop, but most of it leaves the fields as evaporation from the soil and transpiration from plants (evapotranspiration), runoff to rivers and streams, and infiltration to the surficial aquifer.

As the cultivation process of bioenergy production constitutes a majority of water use through the product lifecycle, feedstocks should optimize water efficiently during this stage. Increasing water availability through harvesting rainwater for irrigation, implementing sub-surface drip irrigation, and utilizing reclaimed water (instead of potable water) are approaches that have proven to be successful in many countries such as Israel, Australia and Tunisia (UNEP, 2009).

One way to assess the water impact of bioenergy production is to look at the water footprint (WF), defined as the sum of fresh water required for the production and consumption of the bioenergy. The WF can be further divided into three categories:

- the green virtual water content, which considers the amount of rainwater that the feedstock evaporates while growing. This is relevant to agricultural products. The evaporative loss is included as a component part of the WF because a significant proportion of the water would be available to other water users (e.g. groundwater reserves, ecological features) if the crops were, in fact, not grown;
- the blue virtual water content, referring to the amount of irrigation water (surface and groundwater) that the feedstock evaporates during growth. This is more easily thought of as the water that is not returned to either the surface or groundwater environment. For the production of a product (e.g. ethanol), this is defined as the amount of water withdrawn from groundwater and surface water that does not return to the system from which it came;
- the grey virtual water content, i.e. the water required to reduce contaminants that leaked from the production process into the groundwater to a certain standard (Gerben-Leenes et al, 2009a). For crop production this would be the volume of dilution to reduce to agreed standards nitrate and phosphate (fertilizer) levels and pesticide levels leaching from soils. For industrial production this is the dilution of effluent quality to agreed standards, although this is complicated by the use of downstream municipal treatment plants.

The distinction between green and blue water is extremely important, particularly in crop production given the significant differences in the management of rain-fed agriculture and irrigated agriculture. It also highlights the various "opportunity costs" of water use. Green water generally has a lower opportunity cost than river or lake water, which have numerous other uses in society. Understanding this profile breakdown is important in areas where water competition is high, costs are increasing and rainfall is decreasing or where the suitability of crop growth is under question.Green and blue water are considered direct consumptive use while grey water is an indirect consumption.

A paper by Gerbens-Leenes, Hoekstra and van der Meer (2009) assessed the WF of different primary energy carriers derived from biomass and found large variations depending on crop type, agricultural production system and climate. The WF of average bio-energy carriers grown is 24m3/GJ in the Netherlands, 58m3/GJ in the USA, and 143 m3/GJ in Zimbabwe. The WF of bio-energy is much larger than the WF of fossil energy. The WF of biomass is 70 to 400 times larger than the WF of the other primary energy carriers (excluding hydropower). The trend towards larger energy use in combination with an increasing contribution of energy from biomass will enlarge the need for fresh water, which will cause competition with other claims, such as water for food.

Table 2.3(A) shows the results for the WF of energy from biomass expressed in cubic metres per unit of biomass (fresh weight) for the 15 crops grown in the four studied countries. Differences among WFs of biomass are large, depending on the type of biomass, the agricultural system applied and climatic conditions. For the types of biomass included in this study, the largest difference was found between sugar beets grown in the Netherlands and cotton grown in Zimbabwe; the WF of the cotton in Zimbabwe was 125 times the WF of sugar beets in the Netherlands. There are also large differences within countries. In Brazil, cassava and sugar cane have smaller WFs, while cotton and palm oil show relatively large WFs.

Table 2.3(B) shows the results from the same study per unit of energy provided by the total biomass of the crop for the four countries considered. Because of the variation in water content among crops, a useful metric is to compare dry biomass of WF per energy produced. Still, differences among crops and countries are very large. The largest difference was found between maize grown in the Netherlands and cotton grown in Zimbabwe; the WF of the cotton in Zimbabwe was 40 times the WF of maize in the Netherlands. Within country, there are also large differences between crops. In the Netherlands, rapeseed shows the highest WF or seven times more than the lowest WF for maize; in the USA, the maize WF is five times smaller than the WF for soybeans used for biodiesel. In Brazil, sugar cane and cassava offer the lowest WF per unit of energy compared with the other crops. Likewise, in Zimbabwe, sugar cane shows the lowest WF or 12 times smaller than the highest WF for cotton.

This study was later expanded by Mekonnen and Hoekstra (2011) who calculated more WFs for other crops and countries, also giving global averages. Using data from 1996-2005, the authors estimated the WF of 126 crops at high resolution using a 5 by 5 arc minute grid. Globally, rainfed agriculture has a WF of 5 173 $Gm^3 yr^{-1}$ (91 percent green, 9 percent grey); irrigated agriculture has a WF of 2 230 $Gm^3 yr^{-1}$ (48 percent green, 40 percent blue, 12 percent grey). The authors found that the global average WF per tonne of crop increases from sugar crops (roughly 200 m^3 $tonne^{-1}$) to vegetables (300 m^3 $tonne^{-1}$), roots and tubers (400 m^3 $tonne^{-1}$), fruits (1 000 m^3 $tonne^{-1}$), cereals (1 600 m^3 $tonne^{-1}$), oil crops (2 400 m^3 $tonne^{-1}$) and pulses (4 000 m^3 $tonne^{-1}$). The WF varies, however, across different crops per crop category and per production region

TABLE 2.3(A) - WATER FOOTPRINT OF BIOMASS FOR FIFTEEN CROPS IN FOUR COUNTRIES (m^3/tonne)

Crops	Netherlands	United States	Brazil	Zimbabwe
		m3/tonne		
Cassava			156	1 074
Coconut			444	1 843
Cotton		2 414	1 710	6 359
Groundnuts		477	426	2 100
Maize	153	308	644	3 363
Miscanthus	334	629	828	3 363
Palm oil seed and kernels			1 502	
Poplar	369	696	915	1 198
Potatoes	72	111	106	225
Soybeans		979	602	1 360
Sugar beets	51	88		
Sugar cane		153	128	160
Sunflower	481	1 084	972	2 603
Wheat	150	1 388	1 360	1 133
Rapeseed	459	773	1 460	

Source: (Gerbens-Leenes, et al., 2009)

TABLE 2.3(B) – WATER FOOTPRINT OF BIOMASS FOR FIFTEEN CROPS IN FOUR COUNTRIES (m^3 Gj)

Crops	Netherlands	United States	Brazil	Zimbabwe
		m^3/Gj		
Cassava			30	205
Coconut			49	203
Cotton		135	96	356
Groundnuts		58	51	254
Maize	9	18	39	200
Miscanthus	20	37	49	64
Palm oil seed and kernels			75	
Poplar	22	42	55	72
Potatoes	21	32	31	65
Soybeans		99	61	138
Sugar beets	13	23		
Sugar cane		30	25	31
Sunflower	27	61	54	146
Wheat	9	84	83	69
Rapeseed	67	113	214	

Source: (Gerbens-Leenes, et al., 2009)

as well. When considered on per tonne of product, commodities with relatively large WFs are coffee, tea, cocoa, tobacco, spices, nuts, rubber and fibres (Table 2.3(A). The analysis of WFs of different biofuels shows that bio-ethanol has a lower WF (in m^3 GJ^{-1}) than biodiesel, which supports earlier analyses. The feedstock used also matters significantly: the global average WF of bio-ethanol based on sugar beet amounts to 51 m^3 GJ^{-1}, compared with 121 m^3 GJ^{-1} for maize (Table 2.3(B).

Both water quantity and quality are affected by the bioenergy production. Water constraint is particularly acute with irrigation and when water is diverted from other uses such as food production. Moreover, continuous intensive use of underground water for irrigation could deplete the underground reserves, making the system unsustainable over time. To be economically viable, energy feedstocks will be managed intensively, and this translates into high water-use rates. The water quality also is affected by runoff fertilizers and agro-chemicals. Nutrient pollution could have considerable effects on the water system. According to the International Water Management Institute (IWMI, 2008), 1 percent of global irrigation water supply is currently used for biofuels. A continued strong biofuel expansion could raise this percentage. In the case of India, estimations show that the amount of sugar cane needed to replace fossil fuels by 10 percent by 2030 would mean an increase in irrigation water of 22 000 billion litres (de Fraiture, 2007).

Promotion of crops which have lower water requirements (Jatropha, sweet sorghum, etc.) is one way to respond to competing water uses. Increased water productivity and improved management systems (including water recycling, terraces and soil-covering crops) can also improve water-use efficiency (de Fraiture and Berndes, 2009).

Water is undoubtedly a complex resource for a number of reasons. Unlike carbon, another fundamental and interlinked global management challenge, the impacts and issues around water are localized, historically within the confines of the watersheds and river basins of specific geographical locations. However this is beginning to change through man-made interventions such as inter-basin transfers and, more significantly, the movement of virtual (embedded) water between nations, causing a reliance on water management many miles away from where the virtual water is eventually consumed.

Connected to this is the variability of water over time. For example, water availability varies from year to year due to changing meteorological conditions and countries can vary between the extremes of drought and flood. This variability is likely to increase with the onset of climate change.

Globally, many freshwater ecosystems are suffering from massive overextraction and this poses major social, economic and environmental challenges. These challenges will only be addressed when effective ways can be found to allocate water between competing needs within a catchment, while retaining sufficient water to ensure the continuation of ecosystem functions.

At the core of the issue of managing water within a catchment is a key question: how do we decide and control who can extract water? This process is accomplished through a system of rules that is typically described in terms of the two key concepts of water allocation and water rights:

- a water right is the formal or informal entitlement which confers on the holder the right to withdraw water;
- water allocation describes a process whereby an available water resource is distributed to legitimate claimants and the resulting water rights are

granted, transferred, reviewed, and adapted. Hence, water allocation processes generate a series of water rights governing the use of water within a catchment.

A range of different possible water allocation processes and water rights exists around the world. Appropriate water allocation results in more socially and economically beneficial use of the resource while protecting the environment. Unsuitable or ineffective approaches can drive water stress so understanding water rights and water allocation is important for understanding the solutions to global water stress (Le Quesne et al., 2007).[11]

In some cases, water is sufficiently abundant for use that there is no need for an allocation process. Alternatively, formal and informal control over water extraction may have broken down. These circumstances produce a situation of open access to water. In all other cases, however, a process of water allocation of some form exists that sets out how, by whom, and on what basis decisions are made about who will be entitled to extract water. There are a number of alternative systems of water allocation:

- automatic entitlement. Some water allocation processes recognize an automatic minimum entitlement to water for basic social purposes, or the maintenance of minimum environmental requirements;
- administrative or bureaucratic process. The right to extract water is given by some authority, either a state agency or a user group (e.g. an irrigation board). This is the most widespread formal type of allocation process;
- communal or traditional processes. An enormous range of allocation processes exist that are based on traditional, non-state law or custom;
- market allocation. In some parts of the world, water rights are re-allocated on the basis of trade rather than by administrative allocation. Both formal and informal water markets exist;
- land ownership entitlement. Water rights may be attached to the ownership of land. Transfer of the land through sale or inheritance implies transfer of the water rights. In some cases, landowners abutting a surface water resource are entitled to water rights. Similarly, groundwater below private property is often regarded as an entitlement of that property.

[11] Source: WWF Water Security Series 1 - Allocating Scarce Water - A primer on water allocation, water rights and water markets. April 2007 Tom Le Quesne, Guy Pegram and Constantin Von Der Heyden).

Overall, water resource availability and management is a critical element in any investment for biofuel production in a particular locality. The modalities of water management are, however, local and require consideration of many factors, including the choice of crop and its inherent water demand, the possible long-run sources of water (e.g. rainfall, irrigation and other possible sources of water) and the need to ensure that water use is not only efficient in terms of the amount used per unit of biomass produced, but also sustainable in terms of continued adequate provision of needed blue water over the long run. Judicial or sustainable water management also needs to take into account water policies, communal rights and different systems of water use and sharing among various potential users. Finally, judicious water management also requires preserving water quality or taking measures or steps to minimize damage to water quality resulting from intensive production of biomass.

2.3.8 Land use and preservation of soil productive capacity

Every agricultural activity changes the structure of the soil. For some crops, such as Jatropha, the soil properties can be improved, while for others there is a risk of soil degradation and/or soil erosion. Otherwise, the biomass cultivation effect on soil is the same as for any other crop, except when it involves the introduction of new plants (Jatropha), the cultivation of non-cropland, and the effects of land-use change. Another concern is the potential negative impact resulting from intensive crop management, especially under conventional tillage practices, and intensive use of fertilizers and nutrients; among the consequences are fertilizer runoff and groundwater contamination.

Sustainable soil practices aim to build up or at least preserve the soil quality over time (FAO, 2012a). Tillage practices have an impact on the organic matter which depends on the timing and the kind of tillage applied. Intensive tillage systems such as mouldboard ploughing can be detrimental as they increase risk of erosion, and nutrient loss. In general, light tillage may be favourable to some crops in colder climates, while minimum and no-tillage methods would be preferable in the South (Sullivan, 2004). Increasing the level of organic matter could also improve the GHG savings potential.

Soil-friendly tillage practices (conservation agriculture) can help to better protect soil resources[12]. The main types are intercropping, subsoiling and contour farming:

(a) intercropping involves growing two or more crops in alternating rows on adjacent strips of variable width or in different layers (called under-sown crops) on the same piece of land, during the same growing season. It promotes a favourable interaction between different plant species or varieties;

(b) long-term ploughing and the continued use of heavy machinery can create deep hardpans and compacted soil layers. These may hinder root growth and infiltration of water and nutrients. Subsoiling aims at restoring the lost soil properties and involves loosening compacted soil layers below the ploughing depth, without inverting them. Subsoiling leads to improved root growth and water and nutrient infiltration. It thus helps to reduce surface runoff and boost yields, but it requires a high input of energy;

(c) contour farming involves carrying out field activities – such as ploughing, furrowing and planting – along contours (at right angles to the normal flow of runoff, and not up and down the slope). It aims to create water-retention storage within the soil surface horizon and to slow down the runoff rate, giving water the time to infiltrate into the soil.

2.3.9 Local environmental impact assessment

Many of the current concerns surrounding biofuels stem from poor analysis of the material, nutrient and energy flows that are involved in their production and use. Flawed assumptions about the GHG and ecological benefits of biofuels and bioenergy can lead to promoting poor options. A number of tools can help to quantify material flows, GHG emissions and other ecological impacts; these can be grouped under a range of scientific approaches and tools to assess the sustainability of various production processes. Among these are life cycle analyses and WF and energy balance estimations.

Moreover, many countries have legislation that requires an environmental impact assessment for any given project at local or regional levels. This is a process

---

[12] Source: Sustainable agriculture and soil conservation Soil-friendly farming systems and practices; © European Communities 2009; http://soco.jrc.ec.europa.eu/documents/ENFactSheet-06.pdf

that includes enumerating social, economic and environmental criteria, evaluating the project's impact, scoring or weighing different impacts, and proposing ways to minimize environmental impacts (Pearce and Mourato, 2006, pp 270). In the United States and the EU, the approach is called the Environmental Impact Assessment (EIA), typically carried out at a project level. More recently, a similar framework extended to a programme or policy level has been introduced. This approach – the Strategic Environmental Assessment (SEA) – is based on the following components (Kulsum and Sanchez Triana, 2008):

- screening to see if a policy or project will have relevant environmental impacts;
- deciding which impacts should be included in the EIA/SEA;
- identifying, predicting and evaluating impacts;
- mitigating, i.e. determining how negative impacts should be minimized;
- monitoring, to improve and make changes where necessary.

Another approach, known as the **Downstream Response to Imposed Flow Transformations (DRIFT)**, can be used to evaluate the impact of a project on water resources and flow regimes (basin, watershed, riverbanks, etc.) (King et al., 2004). The method has four components. First, an assessment is made to decide how the ecosystem of rivers is affected by changes induced by a project. Second, an assessment is made on how people who depend on the river are affected by these changes. Third, possible scenarios are considered to predict the future impact on the river ecosystem and users. Finally, socio-economic considerations are taken into account, where compensations and mitigation costs are calculated. Another local-based approach, the Ecological Footprint Analysis (EFA) refers to the area needed to provide the natural resources and absorb the pollution of a project without compromising its capacity to render services (Marchettini et al, 2007).

2.3.10 Integrated environmental assessment and reporting

State of the environment (SOE) reporting has evolved over the past three decades into Integrated Environmental Assessment (IEA) and reporting. With the emergence of the concept of sustainable development – whose three main pillars are economic, environmental and social sustainability – practitioners responded with the introduction of IEA, which integrates social, economic and environmental issues in the analyses.

Integrated environmental assessment and reporting tries to show the cause-effect linkages of human and natural action on the environment[13] and the resultant environmental change in the state of the environment and human well-being. The end result of environmental assessment should be more than just knowing the state of the environment. It should give policymakers and other stakeholders some guidance on how to better manage the environment. In order to achieve this, information obtained should be integrated with other social and economic data and information to assist in policy formulation for the environment. The growing interest in linking environmental, social and economic data and information within the context of sustainable development facilitates integrated analysis of the complex interactions between people and their environment. It is also essential to consider the necessary prerequisites for policies required to promote sustainable development. This is the concept of IEA, which introduces new challenges to the process of environmental assessment:

13 Training Manual on Integrated Environmental Assessment and Reporting – UNEP - http://www.unep.org/geo/pdfs/IEA_Africa_training_manual.pdf

Box 2.2: Soyabean-biodiesel sustainability in La Pampa Province, Argentina

Van Dam et al. (2009a) examined the case of soy in the province of La Pampa situated in the centre of Argentina. To a large extent, the region consists of natural vegetation (e.g. trees, shrubs and grasses) where cattle-breeding is widespread. In the remaining area (30 percent), perennial and annual crops are grown, soy among others. A particular concern for the authors was biodiversity. In particular, the "Bosque de Caldén" is a hotspot for biodiversity where the protection of soils and forestry activities is of great importance. The losses of natural vegetation have been limited to 3.6 percent in 1998-2002. Yet, other parts of Argentina have experienced heavier losses (some reports suggest more than 10 percent). Against this background, the authors aimed to compare how a number of sustainability criteria for soy-based bioenergy were affected by land conversion. Four scenarios were considered:

- current situation – with high importance of pasture, soybean yields of 1.3-2.1 tdm/ha, direct seedling and reduced tillage, small-scale production plants and average environmental awareness;
- year 2030 A – with high importance of pasture, soybean yields of 1.9-3.1 tdm/ha, conventional cropping system and reduced tillage, small-scale production plants and average environmental awareness;
- year 2030 B – with mixed production systems, soybean yields of 1-3.2 tdm/ha, direct seedling and other conservation measures, no tillage, large plants and high environmental awareness; and
- year 2030 C – with very intense pasture production systems, soybean yields of 2.3-3.5 tdm/ha, direct seedling and advanced technologies, reduced tillage, large and efficient production plants and low to average environmental awareness.

For all scenarios, different land types were considered (e.g. abandoned cropland, degraded and non-degraded grassland).

The authors first identified changes of carbon stocks as possible bottlenecks. In the best case (i.e. on abandoned cropland), the soil carbon balance was found to be neutral, while for degraded and non-degraded grassland, the balance was very negative for all scenarios. Similar records were found for biodiversity. The authors found that increased production could lead to a direct or indirect expansion into grassland. They called for continued observations with regard to displacement effects. The GHG reduction potential was estimated to be at least 35 percent for all scenarios over a 20-year period, except for scenario 2030 B when marginally suitable land was considered. Here, the emission reduction potential was estimated as neutral.

In general, the different scenario assumptions had less impact on the outcome than the choice of land. One exception was for soil erosion; the future scenarios including high intensification of livestock production and mixed agricultural production models (2030 B and C) led to improvement of soils when the crop was cultivated on degraded grassland. By contrast, soil erosion was projected to increase when using degraded grassland under current conditions and for Scenario 2030 B on non-degraded grassland.

Box 2.2 (*Cont'd*)

The future scenarios with stronger economic development and environmental awareness (2030 B and C) were expected to be linked with a higher social well-being. The amount of added labour demand due to increased production was rated as neutral for the short term, but could exceed 200 extra jobs for future scenarios. Because human and labour rights as well as land rights are already well defined in Argentina, the impact of soy biofuels on criteria related to these issues was estimated as neutral. To estimate the impact on food security, the authors considered the land prices for future scenarios compared with the current land price, as well as food and feed prices. They found that land prices would increase by 20 percent by 2030 for scenarios A and C, with no difference for scenario B. Also, the food and feed prices were expected to increase, but to what extent the rise would be connected with biofuels as opposed to a general higher growth was unclear.

When considering abandoned cropland, soy bioenergy was estimated as competitive at fossil fuel prices between USD 80 and USD 183/barrel for the export sector and between USD 55 and USD 122/barrel for the domestic sector.

Other analyses looking at the sustainability of Argentinan soybean-biodiesel based on soy include Panichelli et al. (2008). These authors found that soy biodiesel came off worse than conventional diesel in many categories related to environmental sustainability when deforestation was included. Accordingly, they illuminated the possible negative impacts of land-use change. Also, Tomei and Upham (2009) voiced concern related to land-use change. Additionally, they found that the high concentration of the sector could have adverse impacts on smallholders and food security (although they recognized that food distribution was more problematic than food availability *per se*).

- it implies an acknowledgement of the environment and human interactions and the impacts they have on each other over time;
- it incorporates environmental assess-ment into the whole process of environmental policy planning, assessing the impact of policies from different sectors over time and the existing opportunities to promote sustainable livelihoods and options;
- it provides an inventory of available resources which can be used as a starting point for working towards sustainable development;
- it requires the development of appropriate measures to assess existing and changing pressures and opportunities in the environment, and strategies for reducing or containing these pressures, thereby increasing available opportunities in a progressive movement towards sustainable development.

IEA encourages all stakeholders to continually ask whether enough is being done to perceive and utilize opportunities currently available in environmental resources, to achieve sustainable development, reducing poverty, conserving and improving the state of the environment, and to utilize scenarios to construct an outlook.

Box 2.3: Soyabean-biodiesel sustainability in "*Mato Grosso* and *Pará*, Brazil"

Given that nearly 90 percent of the vegetable oil produced in Brazil comes from soy, it is probable that soy will be the most important feedstock for Brazilian biodiesel production in the years to come. A study conducted by Bindraban and Greco (2008) looked at the sustainability of Brazilian soy within the context of the Roundtable of Sustainable Soy. Focus was on Mato Grosso, the region with the largest production of soybeans in Brazil (26.3 percent of total Brazilian production*), and Pará, where the rate of deforestation in the Legal Amazon is currently highest.

As in the Argentinean study, the main problem in Brazil was related to the conversion of land. The analysis by Bindraban and Greco (2008) shows that prices of soybeans are strongly correlated with the land-use change, but the process often follows an indirect path. In general, forests and grasslands are cleared to meet the demand for wood and charcoal. In a second step, the land is sold to cattle breeders. Measures to preserve the soil are usually not taken. The land can be used for dry-land rice after about three to five years and for other crops like soybean after another two to three years. Operators are local or international companies and the requests to clear land are granted by the government. However, illegal deforestation is widespread. As land rights in the Amazon are very complex,** the authors also identified this as a potential problem for social sustainability (e.g. that local populations are removed from their land in favour of large-scale plantations). A countermeasure to combat illegal logging that has shown good results has been to bind private and public credits to criteria rather than fines. In addition, three federal programmes to re-register rural properties are currently running. Even so, the authors concluded that there will be a need to monitor future development. Although direct conversion is low, the indirect impacts could be rather high.

Other problems identified in the Bindraban and Greco (2008) study were related to soil fertility (where monocropping was expected to have a negative impact whereas intercropping in combination with artificial fertilizers and N-fertilizers could have a positive impact, especially when applying non-tillage methods).

Poor labour conditions have been highlighted as a bottleneck by many NGOs. Laws are in place, yet some labour practices have been classified as overexploiting labour. As a result, different stakeholders have created a pact to boycott companies blacklisted by the Ministry of Labour and Employment. The increasing mechanization will probably also lead to better work conditions, both for health and safety. On the other hand, the mechanization also restricts the possibilities for enhancing rural activity. The importance of economies of scale led the authors to assume that the expansion of the feedstock will dislocate many small-scale producers to the cities. Direct job creation of soy on 100 ha is only about two workers per year (substantially less than sugar cane, for example). Generally, production in the North is on a larger scale while in the South, small- to medium-scale production has been prevalent.

The study by Bindraban and Greco (ibid.) did not go further into life-cycle issues and the economic sustainability of soy-based biodiesel production. A report published by the MAPA (2006) indicated that soy biodiesel could be viable at a petroleum price of USD 60/barrel and

* Instituto Brasileiro de Geografia e Estatística, 2008.

** According to Trigueirinho (2008), 40-47 percent of the Legal Amazon is regarded as public property and is currently an issue of dispute.

Box 2.3 (*Cont'd*)

when soybean oil prices are below USD 480 per tonne. However, the report assumed that the costs will decrease after the initial start-up costs and when the industry begins to climb the experience curve. Further, the fact that soy offers a high degree of flexibility and possibilities to diversify the end products makes it appealing for many producers.

GHG emission savings are likely to vary a great deal. A calculation showed a range of -700 to 300 C ha^{-1} $season^{-1}$ depending on the production system (e.g. crop rotation, by-products). When indirect land-use conversion (involving the clearing of Cerrado lands) is taken into account, losses could increase by 30-140 C ha^{-1}. This could lead to a pay-back time of from 15 to more than 100 years (Elbersen et al., 2008). Clearly, a site-specific estimation that takes production methods into account is required to give more specific results (Elbersen et al., 2008).

To sum up, soy biodiesel production is growing in both Argentina and Brazil. This development is likely to continue. A reason for this is the likely ability to diversify production according to market prices on soy meal and other outlets. Soy has the potential to be a sustainable source for biodiesel production. However, the extension into sensitive areas entails risks in both countries.

2.4 Socio-institutional factors in biofuel sustainability

The social dimension of biofuel sustainability relates to the potential for rural development, poverty reduction and inclusive growth. The social (or socio-institutional) dimension of biofuel sustainability can touch on many potentially interlinked issues. This raises a number of methodological difficulties including the challenge of distinguishing between direct and indirect social issues. In this section, we focus on three aspects of social sustainability: land ownership rights, local stewardship of Common Property Resources and labour rights. All these issues more or less tackle a common goal – the need to integrate small-scale farmers within biofuel development and ensure inclusive benefit sharing, safeguarding of basic rights and local means of livelihood consequent to the introduction of biofuels.

2.4.1 Land ownership rights

Climate change and expanding biofuel production are likely to lead to greater competition for access to land. This increased competition poses a threat to the livelihoods of the millions of farmers, pastoralists, fisherfolk and forest dwellers living in areas with no formal land tenure rights. Sound land tenure policies and planning will be crucial.

Given that land is a limited resource, the appropriate use of land depends on the value it can provide to those who hold rights over it. The value can be measured in many ways – e.g. wealth generation, conservation and ecosystem servicing. Biofuels are believed to offer commercial opportunities to enhance the contribution of land to individuals, groups and governments. Access to land (usage or ownership) depends on the decisions of those who hold rights over the land. Those rights may relate to entitlement of ownership or use (e.g. grazing, water) and may be based on national legislation, customary law or combinations of both. In reality, land rights and the processes to gain access to land are often unclear.

Box 2.4: Sugarcane-ethanol usstainability review for Brazil

Brazilian sugar-cane ethanol is one of the rare biofuels produced without heavy public support. Estimated per unit cost is among the lowest (USD 0.25-0.30 per litre). In Brazil, sugar cane has expanded rapidly in the last ten years, mostly at the expense of pasturelands. According to Kutas (2008), sugar cane production could increase from 487 million tonnes in 2007 to 1 040 million tonnes in 2020. This would require an increase in sugar cane area from 7.8 to 13.9 million ha. Most of the expansion is expected to take place in the state of São Paolo (Goldemberg and Guardabassi, 2009).

GHG emissions: For GHG emission savings with Brazilian sugar-cane ethanol, completed LCA studies were reported by Macedo et al. (2008, see also Macedo et al., 2004). In a "seed-to-factory" approach,* they compared energy and GHG balances of fuel ethanol from sugar cane in Brazil with conventional gasoline. In an initial study (Macedo et al., 2008), GHG emissions in production and use of ethanol from sugar cane data from 2005/06 were evaluated and an energy balance of 9.3 was found. Avoided GHG emissions from anhydrous ethanol and co-products (primarily bagasse and electricity surplus) amounted to 2 323 $kgCO_{2eq}m^{-3}$ (for 25 percent ethanol, 75 percent gasoline blend or E25). In a second approach, the energy balance was projected to improve to 11.6 and the avoided GHG emissions to 2930 $kgCO_{2eq}m^{-3}$ by 2020. The sensitivity analysis revealed that cane productivity as well as ethanol yields played the largest roles in both energy and GHG balances. Also the use of bagasse in biomass boilers and for excess electricity gave rise to variation in the results. On the basis of the outcome of this study, Walter et al. (2008b) estimated the avoided GHG emissions compared with gasoline at the pump abroad (Europe); they found that the use of anhydrous ethanol produced from sugar cane in Brazil could save about 70 percent GHG emissions.

A similar result was found by Luo et al. (2008), who observed that the levels of GHG would fall by about 80 percent for use in Brazil. They also considered other environmental impacts such as abiotic depletion (measured in antimony equivalents, a chemical element that can be very hazardous to health), which was reduced by approximately 80 percent. Positive effects were further observed on the ozone layer depletion (ODP), but not for other environmental impacts (human and ecotoxicity, acidification and eutrophication). A possible future scenario included the use of both sucrose and bagasse for ethanol production, while heat and power were generated only by wastes. The results showed improved records for all categories except for the GHG emissions, which increased substantially compared with the baseline. This was explained by the fact that the GHG savings potential is higher for the electricity generation of bagasse than for the use of it as a fuel.

Clearly, Brazilian sugar cane ethanol can generate higher GHG-emission savings compared with other temperate-based biofuels, using an LCA estimation that doesn't factor in land-use change impact. However, there is still considerable debate over whether GHG-emission savings from Brazil's sugar cane ethanol are still positive once indirect land change is taken into account and if sugar cane expansion moves into sensitive areas such as the Cerrado savannah. (Fischer et al., 2008). Nassar et al. (2008) looked into the question of direct and indirect land-use change by

* That is, energy input and output along the ethanol production process but without the distribution and end-use stage.

Box 2.4 (*Cont'd*)

applying a number of different methods. They reported that the sugar cane plantations will likely continue to expand into crop- and pastureland (Nassar et al. (2008). Also, indirect land conversion effects were estimated as low because the productivity of cattle production has increased (and has the potential to increase even further).

Pollution: The Brazilian sugar cane ethanol system also causes air pollution resulting from harvest practices, notably the common practice of field burning before manual harvest to make the cutting easier and to remove snakes and spiders. Cane burning lowers soil quality and organic material, increases the risk for cane diseases (by injuring the stem tissue) and produces higher emissions of CO, CH_4, non-methane organic gases and particulate matter. When tied to manual harvesting, burning raises the risk of respiratory diseases and other health problems for workers.

Recognizing the problem, the government has enacted measures to reduce cane burning and encourage mechanical harvesting, but the latter is not practical in all cases because of topography (e.g. hills, valleys). The federal government has proposed the end of burnings in the existing areas of production according to a schedule of transition. Through this initiative, in the state of Sao Paulo, the use of burning practices is prohibited in areas suitable for mechanical harvesting, which are those above 150 hectares in width and with a slope equal to or below 12 percent. Burning practices are on track to be phased out by 2017 in Saõ Paolo and other states might follow (Goldemberg et al., 2008). This measure will allow reduction in GHG emissions in a volume equivalent to 6 million tonnes of CO_2, considering 2008 as a reference year.

Water sustainability: Because sugar cane is grown in Brazil under rainfed conditions, some argue that impacts on soil and water quality do not pose particular problems (Walter et al., 2008b), especially when biological control methods and biological nitrogen fixers are used. Nonetheless, where production is intense, water pollution and soil erosion should be considered. Measures such as contoured ploughing, absorption terraces and leaving residues on the field are already taken by some producers and could become more common in the future (Walter et al., 2008b).

The impact of sugar cane production on soil erosion depends to a large extent on local conditions (e.g. rainfall, production system, slope gradient) In Brazil, no law considers soil erosion in particular, but it is included in many certification schemes. According to some estimates, the introduction of systems aimed at reducing soil erosion (e.g. contour ploughing, bench terracing, mechanical harvesting without burning) would increase production costs by 3 percent (Walter et al., 2006).

In most of the mills, the ethanol production process requires about $1.23m^3$ of water per tonne of sugar cane. The bulk of this water is recycled. New technologies could even result in ethanol plants becoming water exporters (Neves do Amaral et al., 2008). Although the ethanol production process is relatively energy intense, the use of bagasse for heat and electricity is well-developed. Today, most of the mills are energy-neutral or are exporters of electricity (Macedo and Seabra, 2008). Ethanol processing costs are between USD 0.25/litre and USD 0.30/litre, and production is viable at oil prices of approximately USD 36-43/barrel (BNDES, 2008).

Box 2.4 (*Cont'd*)

Labour issues: Labour is required, above all, for planting, pest control and harvesting. A modern complex with a capacity of 2 million tonnes employs around 2 500 people, although it depends much on the level of mechanization. The seasonal index of jobs in the sugar cane sector (the ratio between labour at harvest and non-harvest) has been estimated at 1.3 in the 1990s (BNDES e CGEE, 2008).

On labour effects and social equity, Macedo (2005) estimated that the biofuel sector in Brazil had generated 800 000 direct jobs in the beginning of the 1990s. Both formal and informal workers (about 69 and 31 percent respectively) generally earned above the minimum wage and more than in other agricultural sectors. The main determinant of labour conditions was the use of technology. Workers in the more mechanized South Central region have a higher degree of education, better work conditions and higher wages. By contrast, the North North-Eastern region has a lower degree of technology, with lower wages and more non-paid workers. Employment of children (minor workers) was also estimated. Macedo (2005) reported that about 0.3 percent of the formal employees were under 17 years old. Brazil has signed the ILO conventions, including the International Labour Organization's Pact for the Eradication of Slave Labour. However, as with Brazilian soy, the problem of forced labour has been pointed out by many NGOs (see e.g. Friends of the Earth Europe, 2008a). In the 2008 report on human trafficking by the US State Department, forced labour on sugar cane plantations was identified as an increasing trend.

Land: In the last few years, the Brazilian Government has targeted the Cerrado – a region as important for its richness in biodiversity as the Amazonas – as a priority area for the expansion of sugar cane, because of its favourable flat topography, good soil quality and high water-supply potential. There is a risk, however, that sugar cane plantations may replace areas of food production or encroach on forest reserves. In the state of São Paulo and surroundings and in the new Cerrados Central-West region, livestock production can be expected to decrease or be displaced to local marginal areas (Sparovek et al., 2007).
Increasing demand for land for sugar cane in Brazil has led in some instances to the conversion of grasslands and wooded savannah for crops, which has released stored carbon dioxide and displaced previous users such as cattle farmers who move into tropical forests in search of new pasture. Indeed, sugar cane land expansion is more than 90 percent from pasture- and other cropland (Oladosu et al., 2009) and has resulted in some land conflicts as plantations have expanded. Small-scale farming has become unviable with many small-scale farmers feeling squeezed into selling their lands. Likewise, leaders of Brazil's indigenous people expressed concerns that plantations were encroaching on their traditional lands, despite the existence of a programme that recognizes indigenous territories (CEO, 2009).

In 2009, the federal Government launched the Sugar Cane Agro-ecological Zoning (ZAE Cana) legislation to guide sustainable expansion of sugar cane production in the future and protect sensitive areas and native vegetation. The decree delineated areas where sugar cane production expansion is allowed and where it is not, including the ban on removing native vegetation for the expansion of sugar cane cultivation.

ZAE Cana prohibits the expansion of sugar cane production and the installation of new units of ethanol production in the Amazon and Pantanal biomes, and in the Upper Paraguay River Basin.

Box 2.4 (*Cont'd*)

ZAE Cana evaluates agricultural potential without irrigation by considering weather and soil conditions and sugar cane varieties in order to select areas in which sugar cane production uses the lowest volume of water possible.

ZAE Cana also serves as an important tool to guide public policies and credit policies in a way that gives priority to sugar cane expansion in areas already used as pasture. Over 34 million ha of land currently underutilized or occupied by livestock or degraded pastures are identified in ZAE Cana as suitable for sugar cane production. The increase in livestock productivity in Brazil (i.e. head of cattle per ha), which today is considered to be low, may provide new areas for sugar cane production.

The suitable areas are more than enough to meet the future demand for ethanol and sugar in the domestic and international markets foreseen for the next decades. In addition, Brazil is investing in the development of technologies for second-generation ethanol production. The use of new technologies for ethanol production, such as the hydrolysis of bagasse that results from crushing the sugar cane, raises biofuel production without further altering the cultivated area.*

* Source: Ministry of Agriculture - EMBRAPA at www.cnps.embrapa.br

Many governments have expressed hope that the development of energy crops may open up the possibility of using unproductive land. However, acquisition of land, even if not currently under crop production, can pose problems if rural communities who may have historical claims to the land for collecting fuelwood or for grazing are unable to protect those claims because they are based on common law and informal tenure systems. As a result, there is a risk that expansion of energy crops may lead to the ouster of vulnerable groups or owners without former documentation. This is all the more likely under governmental decrees or from higher land prices (rent or sale) whereby the poor are generally squeezed out of the market.

The displacement effect might also occur in a more indirect way when bioenergy crops replace food crops: increased rents can cause displacement of food production, along with local users of the original land, to common (perhaps marginal) lands. There is also the potential negative effect of land speculation, by simply acquiring land for biofuels. Such speculation, if not controlled and regulated, can create hardships for small farmers and for agriculture in general. Such indirect impacts might occur on a local, national or – through international trade – even global level. For example, the increasing use of rapeseed for biodiesel in the EU raises demand for other oils both in other parts of the EU (sunflower seed) but also internationally (increased palm oil imports).

Over the past couple of years, large-scale acquisitions of farmland in Africa, Asia and Latin America have made headlines in media reports. These investments have ignited international debate over so-called "land grabs" and their likely impacts (positive or negative) on the environment, rights, sovereignty, livelihoods, development and conflict at local, national and international levels (Cotula, 2011).

While the trend is not new, the scale has hugely accelerated following the 2007-08 food crisis and the almost panicky response over the long-term availability of food supply. However, there are several causes behind these land investments, including the rising global demand for food, constraints in the global food supply, global demand for energy and agricultural commodities and bioenergy policies, including biofuel mandates, as in the USA and the EU. All of these have created a guaranteed market that has encouraged investment in biofuels production in the USA, Europe, Brazil and elsewhere.

Countries in Europe, North America, the Gulf, South Asia and East Asia are all thought to contribute as key sources of investment, although land acquisitions by domestic investors are also significant. Key target countries are in Africa (e.g. Ethiopia, Madagascar, Mali, Mozambique, Sudan and Tanzania), Southeast Asia (e.g. Cambodia, Indonesia, Laos and Philippines) and parts of Eastern Europe (e.g. Ukraine). Von Braun and Meizen-Dick listed more than 50 "land grabbing" cases reported in the media between 2006 and 2009 (von Braun, 2009). The majority of the deals between governments focused on food production.

Quantitative assessments of the scale and location of the land investments are difficult to gather. Empirical evidence is only now starting to emerge from studies conducted in Africa and South Asia. For example, a study released in 2011 by the International Institute for Environment and Development (IIED), FAO and IFAD found that approved land acquisitions from 2004 to early 2009 totaled some 2 million hectares in four African countries alone (Ethiopia, Ghana, Madagascar and Mali). However, reports from national inventories must be treated with caution, as they are likely to underestimate the scale because of limited access to reliable data. On the other hand, many of the deals reported in the media have not been fully implemented (Cotula, 2011). Among private-sector players, agribusiness companies producing biofuels, agrifood or other agricultural commodities account for the bulk of approved acquisitions in Ethiopia, Ghana, Madagascar and Mali.

Country studies from Mozambique and Tanzania also documented high levels of interest in biofuel projects (FIAN 2010). But the borderline between food and fuel is blurred, as the same crop may be used for both, or the same land may be cultivated with multiple crops, and investment plans may evolve over the duration of a project to respond to changing international prices and other incentives. A study by an NGO FIAN International (2010) reported on investment case studies from Kenya and Mozambique. The study focused on the negative human rights implications of these foreign-sourced land investments, sanctioned by the Government but without the implication of the local communities. In the case of Kenya, the FIAN report described a planned public-private joint venture involving Mumias Sugar Company Ltd., Kenya's largest, and the state-run Tana Athi River Development Authority (TARDA) and their joint decision to dedicate 16 000 hectares for a sugar cane plantation for agrofuels. Such a project would affect thousands of small-scale farmers currently using this land for food crops like maize, cassava, beans, vegetables and mango. Pastoralist tribes, such as Orma and Wardei, were also thought to suffer from the deal as the delta has been used as grazing land for their cattle for generations. Human rights groups complained about this venture for its presumed violations of farmers' rights and the lack of their inclusion in the preparatory stages of the project.

A second case described in the FIAN report is from Mozambique, where an investment project tied to agrofuels-oriented export policies of Mozambique received the Government's agreement. This case (also known as ProCana) initially concerned a projected sugar cane plantation of 30 000 ha under a 50-year contract meant to provide ethanol mainly to South Africa. The lands affected are the main source of livelihood of the Massingir communities and are used for livestock raising, charcoal production and subsistence farming. Moreover, the Mozambican Government granted the investors extensive rights for irrigation waters from the Massingir dam. Such (re)allocation of water resources would have posed a challenge for adjacent local communities to produce food. Again in this case, human rights NGOs complained about the project's potential negative effects on the pastoralists by disrupting spaces for livestock grazing and pastoralist routes, or even outright loss of their land without proper reallocation and compensation. In late 2009, the foreign investor announced the withdrawal from the project, and more recently the Government of Mozambique is believed to have cancelled the project.

These cases illustrate that for the sustainability and long-term viability of biofuel projects, it is critically important to involve the local community from the beginning in the project design process to ensure the buy-in of the local populations, safeguarding of their rights and continued access to their resources, chiefly the land. Such an assessment should be undertaken parallel to environmental and economic evaluations of the long-term viability of biofuel development projects and their projected impacts on all key stakeholders.

2.4.2 Local stewardship of common property resources

For many developed countries, the goal of sustainable rural development implies preservation of local productive capacity and natural resources. Mechanization, while generating higher returns on land and labour, has lowered agricultural prices. As a result, government subsidies have been established to prop up farm incomes, and, in the process, have became a constant feature of agriculture in rich countries. In developing countries, safeguarding local productive capacity and natural resources implies local stewardship of Common Property Resources.

Property ownership is a key to stewardship. Common Property Resources (CPRs) are usually non-exclusive resources where a well-defined property regime may not exist and to which rights of use are distributed among a number of co-owners, generally identified by their membership in a community or a village. CPRs may include community forests, common grazing grounds, threshing grounds, rivers and riverbeds. CPRs occupy an important place in the economy of the landless and land-poor, whose employment and income generation opportunity from private property are limited: this is the resource to fall back upon during times of need.

Against the historical and sociopolitical backdrop of foreign oil operations in Latin America and the competitive drive for greater access to new oil fields in sensitive areas, the oil industry finds itself re-thinking traditional approaches to operations in these particular locations. An illustration from Peru is given in Box 2.5.

An illustration from India involves the small tribal village of Mendha Lekha, State of Maharashtra. Here a traditional, participatory forest management is practised. The village is a microcosm of tribal life that has managed to preserve its 18 km^2 of forest over the years using an exemplary principle of self-rule which is central to their existence. Mendha achieved this feat through three pivotal rules: self study, self governance and participatory democracy (a consensus approach). The story of Mendha

Box 2.5: Peruvian Amazon case - importance of stakeholder engagement

In April 2009, the Peruvian Government signed contracts with several companies giving them rights for oil exploration in areas of the Amazon thought to be rich in oil and minerals. Since May 2009, the indigenous communities in the Peruvian Amazon have mobilized themselves and protested against these contracts, seeing them as a threat to their rights and livelihoods. The crux of the protest was against the Peruvian Government's decision which was backed by several laws, but which did not consult with citizens living in territories affected by these contracts, let alone seek consensus or offer compensation.

Following violent and deadly clashes with police, the movement to save the Amazon and its communities forced the Peruvian Government to roll back implemention of its decision. Peru's Congress voted to repeal Legislative Decrees 1090, the Forestry and Wildlife Law and 1064 (the reform to permit changes in agrarian land use without full prior consent), and the President publicly admitted errors in not seeking the opinion of Amazonian indigenous groups. At the same time, however, the Government's view was that huge tracts of the Amazon region were going to waste by not being utilized and that native indigenous peoples have no special land-use rights by birth. But to the local people, the very opening-up of the Amazon to foreign investment raised serious apprehensions about not only the destruction of the jungles but also of traditional knowledge and cultures.

The protests which succeeded in rolling back the Government decision illustrate the importance of consulting and involving local communities in crafting sustainable growth based on social equity.

is unique for many reasons. First, the decision-making process is an informed one in which the villagers, while welcoming all kinds of information from the outside world, retain their right to decide for themselves. Second, decisions are not taken merely by majority but almost always through consensus. Third, transparency is strictly adhered to which makes the entire effort of self-rule successful.

The case of Mendha provides useful insights on the potential of community-managed schemes in tandem with the government that do not sacrifice livelihood, cultural and environmental values. It could become a role model for implementation of government programmes such as the Joint Forest Management (JFM) programme. What is required is to build strong institutions based on a rights-based approach in order to establish the key principles of sustainable development.

2.4.3 Labour/employment effects

For many developing countries, the chance to spur rural employment by producing biofuels has acted as a major driver. Biofuels can spur rural development and stimulate local employment by attracting capital to the agricultural sector and a flow of new technologies including better access to fertilizers, infrastructure and high-yielding varieties. Biofuels production could also increase access to energy services with positive effects on welfare (e.g. by expanding access to electricity and pumped potable water, reducing the workload of women and children who are usually in charge of collecting firewood and improving health by reducing indoor air pollution).

All of these imply new employment opportunities and higher rural wages with positive spillover effects for the local economy (Coelho, 2005).

On the down side, biofuel development could also bring into focus a number of labour-related problems, depending on the type of farm operations and the quality of management. Granting foreign investors a free hand over biofuel-linked production systems carries the risk that they may bring their own manpower along with them, thus negating any employment benefits for local communities. If the local labour force is employed, worker abuse issues that may be prevalent in developing countries could be perpetuated. These may include high seasonal fluctuations in employment, long working days under difficult conditions and weak labour rights (especially in the case of paperless guest workers). To safeguard against these possibilities, it is critical that bioenergy development (including when it is led by foreign investors) proceed in full compliance with the standards established by the Universal Declaration of Human Rights and the International Labour Organization (ILO) Conventions (RSB, 2008a).

ILO Conventions state that farms and plantations cannot become sustainable workplaces if workers do not achieve decent employment and living conditions and if they cannot participate in decisions that affect their lives and work. Child labour is work which abuses and exploits the child or deprives the child of an education. Seventy percent of all child labourers work in agriculture.

FAO, along with ILO, is committed to combating hunger and poverty by promoting rural and agricultural development strategies that are socially, environmentally and economically sustainable, gender sensitive and equitable. Achieving fair conditions of employment means providing opportunities for productive work that delivers a fair income, workplace security and social protection for workers and their families, and better prospects for social integration. The ILO Declaration on Fundamental Principles and Rights at Work is an expression of commitment by governments to encourage fair conditions of employment, including:

- freedom of association and the right to collective bargaining;
- elimination of forced and compulsory labour;
- abolition of child labour;
- elimination of discrimination in the workplace.

The ILO has merged these four areas into the over-arching concept of "decent work." In the interest of promoting a people-centered and rights-based approach to development, upholding these fundamental principles and rights at work – including elimination of child labour in agriculture – remains a key priority for ILO in its collaboration with FAO and other concerned organizations.

It is noteworthy that whether or not countries are signatories to ILO conventions means very little in terms of the actual health and well-being of the labour force, concerning which there is often a dearth of data. Much remains to be done to establish the requisite institutional machinery to enforce these principles.

Overall, the social dimension of sustainable biofuel production, trade and use requires adhering to a number safeguards, such as ensuring human rights to local communities when investments in land and potential relocation and compensation are required; integrating small-scale farmers and the local population, including women, in the biofuel supply chain through out-growers schemes; ensuring that new biofuel developments bring maximum employment opportunities for local populations; and ensuring that international standards for workers' rights, including those enshrined in the concept of "decent work", are fully respected and maintained. These prerequisites improve the chances of social acceptance and hence place the local communities on a path towards social sustainability.

2.4.4 Social sustainability assessment

The social dimension of sustainability can be evaluated in the context of a biofuel project or an investment initiative in a number of ways. One particular method is the Social Impact Assessment (SIA), which involves an evaluation of impacts on employment, wages, health, gender inclusion, etc. Like the Environmental Impact Assessment (EIA), the SIA combines both qualitative and quantitative methods, but relies to a larger extent on the participation of different stakeholders (Harrison et al., 2009). Often, large surveys are carried out based on standardized questionnaires coupled with expert interviews and group discussions; illustrative case studies are given in (UNDP, 2006) and (Lindblom and Rasmussen, 2008). Moreover, a number of tools are available to incorporate specific issues in the project analysis, such as gender, community risk, etc. (Keam and McCormick, 2008).

Depending on the activity being evaluated and its location, an SIA may encompass a variety of separate studies on specialized topics, such as: impacts on human rights, indigenous peoples, economic and physical resettlement, community health or conflict situations. Like an EIA, an SIA should result in a report containing recommendations about ways to avoid, minimize and mitigate potential impacts. Project leaders should then decide which recommendations they will adopt and develop a system commitments register in order to list the commitments, track their progress and report to relevant stakeholders, such as the affected communities.

Having completed an assessment of the economic, environmental and social dimensions of sustainability, we now turn to an overview of the bioenergy sustainabililty initiatives at national, inter-governmental and private multistakeholder entities.

2.5 Initiatives on bioenergy sustainability

An increasing number of countries, as well as private entities and multistakeholder groups, have established initiatives in biofuels sustainability. In the chapter, we review the main initiatives in biofuel production, including from Europe, the USA, Brazil and several other leading developing countries. In addition to country-based initiatives, this section also covers inter-government, private and multistakeholder voluntary standards and initiatives related to biofuel sustainabilty. Our chief concern is to ascertain the scope of sustainability that these various initiatives cover.

2.5.1 National initiatives

We begin this section from Europe, a region that t took the lead in pushing for sustainability initiatives out of necessity due to its relatively strong dependency on imported feedstocks and biofuels. The EU anticipate that over 40% of EU biofuel consumption in 2020 will be derived from imports, most of this from developing countries (German and Schoneveld, 2011). Therefore, ensuring that these imports meet its own standards emerged as priority.

This review with the European countries that took the lead in the process, namely the Netherlands, the United Kingdom and Germany, eventually paving the way for the EU-wide directive on bioenergy sustainability.

The Netherlands

The Netherlands was among the first European countries to initiate national-level initiatives on biofuel sustainabiltity, along with the United Kingdom and Germany. The starting point was the considerable growth in the use of biofuels for "green" electricity generation in the Benelux countries from 2005–2007. In 2006, the "Dutch assessment framework for sustainable biomass" was initiated, and in 2007 a report was issued emhpasizing six sustainability categories, namely:

- GHG emissions;
- competition of biofuels with food production;
- biodiversity;
- environmental effects on water, air and soil;
- prosperity of the local economy; and
- social well-being of the local population and employees.

The report went even further by specifying criteria and principles for each category, but it was soon considered too ambiguous and unpractical, especially in the absence of an enforceable directive at the EU level at the time. Consequently, compliance with the sustainability requirements included in the report was not a precondition for commercializing biofuels in the Netherlands, but companies supplying biofuels to the Dutch market or using biomass for power generation are obliged to report the information available to them on the carbon performance and sustainability performance of their product.

During that period, the Dutch Government set ambitious goals for green electricity production: 6 percent in 2005, 9 percent in 2010 and 17 percent in 2020. In addition, the Dutch Ministry of Environment signed an agreement with electricity producers to reduce carbon dioxide emissions by 3.2 million MT between 2008 and 2012.

In 2007, some 2 percent of the petrol and diesel sold in the Netherlands had to consist of biofuels. In October 2008 the Dutch government reduced its biofuel targets for 2009 and 2010, from 4.5 percent to 3.75 percent and from 5.75 percent to 4 percent, respectively. The most important reason behind this adjustment is the concern regarding the effectiveness and sustainability of biofuels.

Moving forward, biofuel sustainability became a key policy objective, and for the Netherlands this could only be achieved through bilateral cooperation with producing countries to support more sustainable production chains.

Following the European Commission's Renewable Energy Directive (RED), published on 25 June 2009, the Netherlands set out to implement its provisions for GHG emissions (i.e. reductions by 35 percent relative to fossil fuels), measured over the entire chain (from production of raw materials through to end-use). In addition, there were other preconditions for the type of land on which biomass may be cultivated. These sustainability criteria were applied to biofuels for transport, as well as to bioliquids for the heating or electricity sectors.

Since January 2011, the Netherlands launched a new system by the standardization institute NEN and the Rotterdam Climate Initiative (RCI) to assess the sustainability requirements for solid, liquid and gaseous biomass for energy application and transport fuels. The certification is handled by private accredited certification service providers.

United Kingdom

A similar initiative on biofuels sustainability was developed in the United Kingdom at about the same time as in the Netherlands, with the two countries collaborating closely (van Dam et al., 2008). In 2005, in anticipation of the impending implementation of the Renewable Transport Fuels Obligation, the United Kingdom's

Low Carbon Vehicle Partnership established that it would be possible to apply a "meta-standard" approach to the implementation of sustainability assurance (including environmental aspects) to biofuels supplied in the United Kingdom. The meta-standard was developed by comparing the principles, criteria and indicators developed by existing and emerging voluntary standards around the world, including the Forest Stewardship Council (FSC), Roundtable on Sustainable Palm Oil (RSPO) and Europe food retailers common standard for farm management (EurepGAP).

A set of seven basic principles were identified to define the Renewable Transport Fuels Obligation (RTFO) sustainability meta-standard, each principle including a number of criteria and indicators. Therefore, by permitting the use of existing certification schemes around the world, including the United Kingdom's Assured Combinable Crops Scheme (ACCS), the cost and administrative burden of compliance is minimized.

Effective in April 2008, the United RTFO to reduce its dependence on fossil fuels and GHG emissions from the road transport sector, as well as to increase the share of sustainable biofuels (GBEP, 2008). The RTFO is based on a certificate system. To obtain a Renewable Transport Fuel (RTF) certificate, the biofuel quantity is registered by the Renewable Fuels Agency (RFA). The certificates can be traded.

Only those organizations that supply more than 450 000 litres of fossil fuel in a given year are obligated by the RTFO. Since 2010, biofuel must constitute 3.5 percent of the fuel sold in United Kingdom petrol stations. The amount of biofuel that must be supplied increases annually until April 2013 when it will reach 5 percent of total road transport fuel supplied by volume. It will remain at that level for subsequent years. In addition, RTFO sets out seven voluntary sustainability principles – five environmental and two social – on which companies must report to the RFA, which then publishes the findings on a quarterly basis. This "name and shame" approach was intended to provide public exposure of firms and force them to comply with the established sustainability criteria. Fgure 2.6 compares several initiatives and how far they meet some sustainability standards.

Owners of biofuel at the duty point are awarded one Renewable Transport Fuel Certificate (RTFC) per litre of biofuel or kilogram of biomethane supplied. RTFCs may be earned irrespective of the volume of biofuel owned, providing a potential revenue stream for even the smallest suppliers. RTFCs may be traded between participants in the scheme.

Under the RTFO, the RFA also requires annual, independently verified reports of overall supplier performance from suppliers applying for certificates, attesting to the sourcing of sustainable biofuels with good GHG savings. To independently validate the accuracy of carbon and sustainability reports, a Chain of Custody must be established from the feedstock producer to the fuel supplier (an existing standard may operate its own certifiable Chain of Custody, specific to the feedstock and standard).

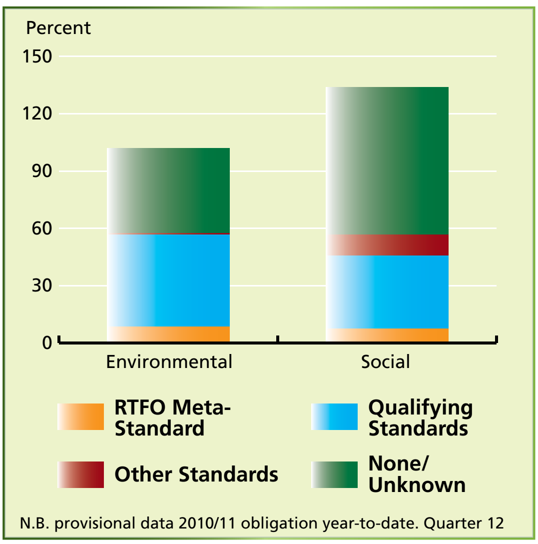
Detailed technical guidance for sustainability reporting under the RTFO parallels that proposed by the Netherlands and Germany with the aim of harmonizing activities among the three countries. This ultimately formed the basis for the EU-wide directive. Parallel to this were international initiatives for setting global standards, especially the Global Bioenergy Partnership established by the G8 after the Gleneagles Summit and the UN-FAO through its Global Bioenergy Platform and through the Global Roundtable on Sustainable Biofuels.

More recent results are contained in a 2011 report by the RFA, which assesses the impacts of biofuel supplied in the second year of the RTFO. Year two of the RTFO has seen an increase in reported numbers of both biofuel feedstocks (mainly cereals, sugar and oilseeds) and their countries of origin. The report includes analysis of the most common sources, looking at the sustainability impacts of agricultural production and opportunities for improvement.

The report shows that industry as a whole is not keeping up with escalating targets designed to encourage more sustainable biofuels. Just 31 percent of biofuel feedstock met a Qualifying Environmental Standard, well below the target of 50 percent. The majority of suppliers also missed the GHG target of 50 percent, but the RTFO as a whole achieved 51 percent savings compared to fossil fuels. Despite the poor performance by many, the report also identifies suppliers who are demonstrating what can be achieved.[14]

[14] The full report and supporting studies, containing a wide ranging examination of the impacts of UK biofuel use, are available at: www.renewablefuelsagency.gov.uk/yeartwo.

FIGURE 2.6 - PROPORTION OF BIOFUELS MEETING SUSTAINABILITY STANDARDS



Source: RTFO (2011)

Germany

The German Biofuel Quota Act (BQA) came into force in 2007. In Germany, biofuel blending mandates were readjusted by adding sustainability requirements: the 2007 BQA was adjusted down for 2009, from 6.25 percent to 5.25 percent (based on the energy content), which would rise to 6.25 percent starting in 2010. After 2010, sustainability of production became a requirement, and by 2015, accreditation of biofuels will be based on GHG emissions savings rather than on the energy content (Bundesregierung, 2008 and BMU, 2008).

The German Biomass Sustainability Ordinance (BSO), initiated in 2007, focuses on environmental criteria only,[15] namely the protection of natural habitats, air, water and soil as well as the impact of biofuels on climate change. According to BSO, starting in 2011, biofuels should have GHG emission savings of at least 40 percent. Also, from January 2009, under the revised Renewable Energy Act and the new Renewable Heat Act, new sustainabililty criteria were specified for renewable energies in order to qualify for compensation. (EEG, 2008, EEWärmeG, 2008).

Renewable energy act

The goals of the German government's "Climate Package," are to save 250 million metric tonnes of CO_2 by 2020 and to use renewable energies to generate 30 percent of total electricity by the same year. From 2009 onwards, all new buildings were to have heating systems based on clean energy, and financial incentives were to be made available to equip older buildings with such technologies. These laws provide a ready-made market for investors in energy-efficient heating technologies such as biomass pellet

[15] The draft from 24 October 2007 included standards on minimum work requirements (e.g. no slavery or child labour) in accordance with the ILO, but were cancelled in the resolution from 5 December 2007 because of possible inconsistencies with the WTO rules (Wolf, 2007).

heating, and biomass-based Combined Heat and Power (CHP). The federal government has made €750 million available annually to support CHP projects. Investors can receive feed-in tariffs of 7.79-11.67 Eurocent/KWh for electricity from wood, forestry residues, organic wastes or energy crops converted into electricity via combustion, gasification or biogas fermentation systems. The feed-in tariff is the compensation paid to owners of renewable energy systems when they sell their electricity to the public grid. There are bonus incentives to encourage the use of certified sustainable raw materials, and for the simultaneous use of biomass in CHP (or co-generation) plants, known for their high efficiency.

Renewable heat act

The climate package also calls for the promotion of heat from renewable sources. All new homes built after 1 January 2009 must provide 14 percent of their heating and hot water energy with renewable sources, and the government offered USD 517 million a year in grants for homeowners to install renewable energy systems such as solar panels, wood pellet stoves and boilers, and heat pumps. The essential aim of the Renewable Energies Heat Act is to increase the share of renewable energies in heat provision in Germany to 14 percent by 2020.

Overall, this short overview of the sustainability initiatives from three key European countries shows that implementation proved difficult because of the absence of an all-EU enforceable directive. The logical next step was for these national initiatives to merge into an EU regulation setting enforceable criteria for sustainable biofuels, biomass and renewable energy.

European Union

Following the initiatives in individual European countries described above, the EU developed an EU-wide directive on renewable energy, stipulating a number of criteria for "sustainable" biofuels. The EU issued a Revised Fuel Quality Directive (RFQD) and the Directive on Promotion of Renewable Energy Sources (RED), which was approved in December 2008 and became effective in July 2009.

The RFQD requires a 6 percent reduction of GHG emissions from production and combustion of transport fuels from 2011 to 2020 (EP, 2008a). However, it does not specify how fuel companies shall reduce the emissions of supply and is not limited to biofuels only.

The European Community sought to implement these targets with a wide range of measures, covering emissions reductions, energy efficiency measures, green public procurement rules in transport and the promotion of renewable energy sources for the transport sector. Under Directive 2003/30/EC, the EU established the goal of reaching a 5.75 percent share of renewable energy in the transport sector by 2010. The Directive on Promotion of Renewable Energy Sources (RED or EU RES-Directive) focuses only on renewable energies. It mandates a share of 20 percent of renewable energies in general, and of 10 percent for transport in particular, by 2020. For biofuels/bioliquids to be counted as renewable energy, a minimum GHG saving of 35 percent is required by 2014, 50 percent between 2014 and 2017 and 60 percent or higher after 2017 (EP, 2008b).

The directive also stipulates "no-go" zones for feedstock production, such as areas where land is deemed to be of "high biodiversity value" or "high carbon stock". Primary forest and highly biodiverse natural and non-natural grassland, as well as other protected areas, would fall under this category. The directive also applies to wetlands, continuously forested areas and peatland, if conversion has taken place after January 2008 (EP, 2008b, Article 3 1-4 and Article 17 2-5).

The RED requires the economic operators in the member countries to report on the fulfilment of the GHG requirements as well as on the progress on other criteria (EP, 2008b, Article 17 7: 19 6; 18 1).

However, under the implementation guidelines of the directive, in cases where precise calculations on GHG reduction cannot be made for feedstock grown outside the EU, the reporting can be based on default values for GHG calculations. The use of "severely degraded" and "heavily contaminated" land that was not in use for agricultural purposes as of January 2008 is encouraged by offering a bonus of 29 g CO_{2eq} per MJ. The bonus will be valid for ten years as long as there is a continuous augmentation of carbon stocks and reduction of erosion and soil contamination (EP 2008b, Annex V C 7-9).

Where biofuels and bioliquids are made from raw material produced within the Community, they should also comply with Community environmental requirements for agriculture, including those concerning the protection of groundwater and surface water quality, and with social requirements. However, there is a concern that production of biofuels and bioliquids in other countries might not respect minimum environmental or social requirements as different countries operate under different systems. However, such deviations across countries can only be tackled through multilateral and bilateral agreements and voluntary international or national schemes that cover key environmental and social considerations, in order to promote the production of biofuels and bioliquids worldwide in a sustainable manner (European Union, 2009).

Implementation of the RED was assigned to accredited voluntary national and international schemes. As of July 2011, seven voluntary certification schemes were approved by the EU. These are: International Sustainability and Carbon Certification (ISCC), Bonusucro EU (EU standard for sugar cane-based ethanol), Roundtable for Responsible Soybean (RTRS EU RED), Roundtable for Sustainable Biofuels (RSB EU RED), Biomass Biofuels Sustainability voluntary scheme (2BSvs), Abengoa RED Bioenergy Sustainability Assurance (RSBA) and Greenergy Brazilian Bioethanol verification programme. These voluntary national or international schemes set standards for the production of biomass products and must provide sufficiently accurate data for the purposes of the RED (Article 17(2)) or demonstrate that consignments of biofuel comply with the sustainability criteria set out in the directive. The Commission requires these schemes to provide sufficiently accurate data on measures taken for the conservation of areas that provide basic ecosystem services (such as watershed protection and erosion control) in critical situations for soil, water and air protection, for the restoration of degraded land, and for the avoidance of excessive water consumption in areas where water is scarce, as well as on the issues referred to in the second subparagraph of Article 17(7) on social sustainability.To ensure that biofuels and bioliquids meeting the sustainability criteria can be traced, the mass balance method is required to verify compliance (European Union, 2009).

The Commission deferred consideration of other sustainability criteria, such as soil and air quality, water access, labour rights and other social criteria until 2012. For indirect land-use change, starting in 2010, the Commission proposed guidelines to follow using an appropriate methodology based on the best available scientific evidence.

United States

In the United States, the national policy on low carbon fuels is reflected in the Renewable Fuel Standard (RFS) passed in 2007 and the RFS2 policy regulations put in place by the Environmental Protection Agency (EPA) in 2010. The RFS calls for a combined use of 140.4 billion litres of biofuels by 2022, of which 58.5 billion litres are conventional biofuels (corn ethanol) and the remainder, 81.9 billion litres, are from advanced biofuels.

Under RFS2, some renewable fuels must achieve GHG reductions – compared with the gasoline and diesel fuels they displace – in order to be counted towards compliance with volume standards. Conventional biofuels, as defined under RSF2, means practically corn ethanol, which is required to achieve at least a 20 percent reduction in GHGs compared with fossil fuels. The advanced biofuels requirement under the RFS covers cellulosic, biomass-derived diesel and "other" advanced biofuels (e.g. sugar cane ethanol, algal-based biofuels). The overall GHG requirement for the advanced biofuels is a 50 percent GHG reduction. However, the cellulosic biofuels requirement, which at the passage of the RSF was thought to comprise the majority of the advanced biofuels requirement, must achieve at least a 60 percent GHG reduction. However, the EPA has revised its projected share of different advanced biofuels and significantly lowered the share of cellulosic ethanol because of continued delays in commercial deployment of this advanced biofuel.[16] Still, a sticky point relating to the appropriate methods to calculate indirect land-use change remains unresolved.

In the United States, biofuel sustainability is entrusted with the Council on Sustainable Biomass Production (CSBP), a multistakeholder organization established in 2007 to develop voluntary sustainability standards for the production of biomass and derived bioenergy products.

In California, there is one major state-level biofuels policy, the Low Carbon Fuel Standard (LCFS), which requires California to lower the carbon intensity of its transport fuel pool by 10 percent by 2020. LCFS aims to achieve the 10 percent reduction in average carbon intensity by starting specified providers of transport fuels at an initial 2011 level, and incrementally lowering the allowable carbon intensity for transport fuels used in California in each subsequent year through 2020. The fuel providers can meet the annual carbon intensity levels with any combination of fuels they produce or supply and with LCFS credits generated in previous years or acquired from other regulated parties.

Brazil

In Brazil, a voluntary agro-environmental certification scheme exists for ethanol producers located in the state of São Paulo. The emphasis is on management practices (faster phase-out of burning habits, protection of water, air and soil, and maintenance of biodiverse areas). It also considers fair labour practices (Etanolverde, 2009). According to the Special Secretariat of Environment in São Paulo, 82 percent of the producers in São Paulo complied with the guidelines in 2008 (amounting to about 17 percent of the global ethanol production) (Lucon, 2008). At a federal level, the programme "Programa Brasileiro de Certificação em Biocombustíveis" is currently working on a voluntary certification scheme based on social and environmental criteria (see INMETRO, 2009 for more information).

Brazil's strategic goal is the creation of a global ethanol commodity market, which would involve the promotion of ethanol production in other developing countries and the negotiation of agreed standards. In light of growing critiques of biofuel production, the discussion on standards has expanded to include environmental and social criteria. Inmetro, the National Institute for Metrology, Norms and Industrial Quality is in charge of this programme and pilot projects were being tested on a

[16] EPA-released 2012 programme for implementation of EISA includes only 3.5 million gallons for cellulosic ethanol out of a total of 15 billion gallons for advanced biofuels.

regional sample of sugar-mills. In addition to physico-chemical criteria relating to the quality of the sugar cane, respect for labour legislation (slave labour) and levels of GHG emissions are also included. It is hoped that this voluntary certification will provide the passport to global market access (Wilkinson, 2008).

The Social Seal for Biodiesel is another attempt to improve the social sustainability of Brazilian biofuels. It offers tax reductions and preferential credits for biodiesel suppliers who use feedstock (typically Jatropha and castor beans) purchased from small-scale farmers. Results have been mixed. Brazilian biodiesel is more expensive than ethanol and small-scale cultivation is generally less efficient than large-scale production. Accordingly, most of the biodiesel (over 80 percent) is based on soybean, which is cultivated mainly in large plantations (Walter and Segerstedt, 2008).

Canada

The Canadian government's goals are aimed at integrating environmental sustainability with human health and economic competitiveness. The Canada Revenue Agency (CRA) operates with approximately 40 000 employees working in over 150 offices in 65 communities across Canada. It has a significant environmental footprint, which can be reduced by adopting best practices in environmental management and sustainable development. Its vision for sustainable development is that the way in which it administers programmes and promotes compliance with Canada's tax legislation will contribute to the economic and social well-being of Canadians and ensure a sustainable environmental footprint. The CRA Sustainable Development Strategy, 2007-2010, has four goals that are supported by nine objectives and 16 targets. The CRA's mandate contributes to all three pillars of sustainable development: economic prosperity, social well-being, and environmental protection (CRA, 2006).

Canada, which is a major producer and exporter of wood pellets and also produces ethanol from grain, currently relies on voluntary certification to promote sustainability in the biofuels industry. Launched in 1988 as Canada's national eco-labelling programme, EcoLogoM is an independent third-party, green-certification organization. The certification label screens for a wide range of products and services deemed preferable or less harmful to the environment. The label depends on consumer preference for environmentally-sustainable products, thus providing a marketing advantage to companies who acquire certification. The EcoLogoM has criteria for renewable energy sources with specific criteria for biomass and biogas.

Malaysia

According to MPOC, Malaysia is committed to sustainable agricultural practices for cultivation and processing of palm oil for use in foodstuffs and oleochemicals (MPOC, 2008). According to the MPOC, palm oil certification for sustainability is actively pursued to ensure access for Malaysian palm oil exports to the EU market. One of the voluntary standards used in Malaysia is EurepGAP23, an Integrated Farm Assessment, used as a worldwide standard for combinable crops. Although it focuses mainly on food safety with limited criteria on environmental and social sustainability, several palm oil plantations in Malaysia are currently certified by the Fruit and Vegetable Standard of EurepGAP (Dehue et al., 2008).

Indonesia

Indonesia and Malaysia, the two largest forest product exporters in the Asia-Pacific region, have both developed regional forest certification systems: the Lembaga Ekolabel Indonesia (LEI) and the Malaysian Timber Certification Council (MTCC) respectively. As regards palm oil, based on the 8 Principles and 48 Criteria for sustainable palm oil production published in October 2005 by the Roundtable on Sustainable Palm Oil (RSPO) and further elaborated in June 2007, both Indonesia and Malaysia were, as of February 2008, developing national sets of indicators (BTG, 2008).

The Indonesian NGO Sawit Watch urged the RSPO to set up a taskforce on smallholders, with the objective of ensuring their effective participation so as to revise RSPO standards to suit their needs. The task force recommended revising the standards and developing new verification and compliance procedures to ensure more effective participation of 4 million Indonesian small-scale oil palm producers. Another local NGO (Milieudefensie, Lembaga Gemawan and Kontak Rakyat Borneo) requested that large oil plantations adhere to the RSPO criteria and follow their own published standards.

Other examples of countries promoting sustainability are China, India, Japan and Switzerland. The Quality Council of India is entrusted with planning certification procedures for biofuels under the national biofuel policy strategy (Chaturvedi, 2009). China only promotes the expansion of biofuel capacities based on non-food crops. In Japan, the "Act on the Promotion of Producing Biofuels from Biomass of Agriculture, Forestry, and Fisheries" contains some principles on environmental sustainability, food supply and the production process. Finally, in Switzerland most suppliers of biofuels have to demonstrate that the feedstock was grown under sustainable conditions in order to qualify for bioenergy subsidies (GBEP, 2008).

2.5.2 Intergovernmental initiatives

Beyond initiatives at the national (and supranational) level, there are also several intergovernmental initiatives looking at bioenergy sustainability issues. Some of these, such as the Global Bioenergy Partnership (GBEP), serve as global platforms for arriving at consensus on the themes for indicators defining sustainable bioenergy systems (FAO, 2011b). Some also serve as the basis to arrive at workable certification schemes that can apply across borders.

Global bioenergy partnership

In the July 2005 Gleneagles Plan of Action, the G8 +5 (Brazil, China, India, Mexico and South Africa) agreed to "... promote the continued development and commercialization of renewable energy by, among other measures, launching a Global Bioenergy Partnership to support wider, cost effective, biomass and biofuels deployment, particularly in developing countries where biomass use is prevalent."

The GBEP was launched during the Ministerial Segment of the 14th Session of the Commission on Sustainable Development (CSD14) in New York on 11 May 2006. Since 2005 GBEP has received renewed mandates from G8 Leaders every year. The G8 Camp David Summit applauded "the Global Bioenergy Partnership (GBEP) for finalizing a set of sustainability indicators for the production and use of modern bioenergy and for initiating capacity building activities through a Regional Forum in West Africa." The G8 Leaders also invited "GBEP to continue implementing capacity building activities that promote modern bioenergy for sustainable development". (G8 Summit Energy and Climate Change Declaration, Camp David, 19 May 2012).

Among GBEP's main functions are:

- to promote global high-level dialogue on bioenergy policy-related issues and facilitate international cooperation;
- to support national and regional bioenergy policy-making and market development;
- to favour the transformation of biomass use towards more efficient and sustainable practices; and
- to foster the exchange of information and skills through bilateral and

multilateral collaboration, not only North-South, but also South-South, South-North, and North-North.

GBEP brings together public, private and civil society stakeholders, involving 46 countries and 23 International Organizations. Among its current partners and observers are several African countries which include Angola, Egypt, Gambia, Ghana, Kenya, Madagascar, Mauritania, Morocco, Mozambique, Rwanda, South Africa, Sudan, Tanzania and Tunisia. Its Secretariat is housed at FAO Headquarters in Rome, mainly with the support of the Government of Italy.

GBEP agreed (20 May 2011) on a set of twenty-four sustainability indicators for bioenergy, intended to guide any analysis undertaken of bioenergy at the domestic level with a view to informing decision making and facilitating sustainable development of bioenergy. In December 2011 GBEP published its report on the sustainability indicators for bioenergy, which includes methodology sheets to guide their measurement. GBEP has also agreed to focus future activities on capacity building for sustainable bioenergy.

2.5.3 Private and multi-stakeholder sustainability initiatives

There are a number of private voluntary national and international certification bodies dedicated to biomass and biofuel sustainability. Some of these are biomass-specific (e.g. sugar cane, soybean, palm oil), while others are multicommodities and multibiofuel initiatives (e.g. the Roundtable on Sustainable Biofuels, ISCC). A noteworthy private initiative on biofuel sustainability is the Roundtable on Sustainable Biofuels, established by the Ecole Polytechnique Fédérale de Lausanne (EPFL) Energy Center in 2006. It is a multistakeholder project with the objective of developing international principles and criteria for sustainable biofuel production. Participants are NGOs, national governments, intergovernmental organizations, energy firms and farmers and producers. The draft principles and criteria from 2008 are depicted in Table 2.4, column 1. The RSB also developed a set of indicators for some principles and criteria to assess compliance. The framework set up by the RSB primarily aims at providing implementable guidelines, information and support for stakeholders.

Similar multistakeholder attempts with representatives from private and public sectors in the United Kingdom have also been set up at a national scale. For example, the Low Carbon Vehicle Partnership (LowCVP) has a working group on fuels, which has been involved in the outline of sustainability principles and criteria (LowCVP, 2009). In the United States, the Sustainable Biodiesel Alliance (SBA) is modelled on the RSB model but concentrates on the USA biodiesel market (SBA, 2009). Members are primarily NGOs, family farmers and environmental organizations (for more information, see LowCVP, 2009 and SBA, 2009).

Other standard setting organizations that are currently not involved in the bioenergy certification but could be relevant for the social sustainability in the future include the Fairtrade Labelling Organization (FLO) and the Ethical Trading Initiative Code of Conduct (ETI Base Code).

Apart from certification organizations, many NGOs are also involved in the monitoring and evaluation of biofuel activities. The World Wildlife Fund (WWF) has been active in the certification process of many initiatives both within the roundtables and as publisher of reports and position papers. Aliança da Terra (AT) has initiated the project “Doing It Right” together with one of the largest agricultural processors in the world, Archer Daniels Midland Company (ADM), to support sustainable soy production in Brazil (ADM, 2009). Other active NGOs are Friends of the Earth and Greenpeace, which have been rather critical of the fast bioenergy development and have prepared various reports (see e.g. Friends of the Earth, 2008a and b; Wood, 2009).

In summary, once these standards, criteria, and indicators are sufficiently detailed, their implementation can be made operational in many ways including via a certification scheme. In the latter case a certification organization acts as an implementation body. The most relevant certification schemes will be discussed in detail in Chapter 3 of this report.

2.6 Conclusion

This chapter discussed the economic, environmental and social dimensions of sustainability in in the context of biomass development. The following conditions were evaluated: when does biofuel production make sense from an economic point of view; what impacts increased production may have on competing feedstock uses (primarily food); and to what extent biofuels can be a substitute for limited fossil fuels. Various environmental impacts were also taken into account: GHG emissions, soil stress, air and water pollution, as well as biodiversity. Social sustainability aspects were considered as well, such as rural development, common property management, labour and land rights, as well as equity issues. Because these various dimensions of sustainability interact with each other it is important to take a holistic approach. Many governments and NGOs take the position that development of sustainable biofuels entails finding a state of equilibrium between environmental interests (conservation of ecosystems) and the economic and social interests of the rural community users and the society at large.

Economic viability of biomass can be assessed in terms of profitability (the price of the biofuel exceeds the production cost) and efficiency (the maximum amount of yield is obtained with a given quantity of resources). The economic competitiveness of biofuels calls for their price to remain below the price of oil equivalents. However, analysis is clouded by distortions, tariffs and subsidies which can mask true economic assessment. The persistence of production subsidies in support of biofuels calls into question the economic viability of these systems without such subsidies, outside of Brazil's sugar cane ethanol. However, producers' decision-making about whether to engage in biofuels development also depends on alternative uses of the feedstock crop and associated prices for the respective end-products vis-à-vis biofuels. The prices of these end-products help set the price floor for biofuels.

The food crisis of 2007/08 heightened the debate about biofuels development and food security (availability of and access to food). While competition over resources such as land, water and fertilizers can potentially constrain food availability (depending on feedstock and location), bioenergy development does not automatically generate any such impact. On the contrary, if crop rotation is practised, whereby cereals are alternated with leguminous plants containing nitrogen-fixing bacteria, the production of biodiesel feedstock could even increase cereal yields for food.

In developed economies the impact of biofuels on food prices is expected to be limited while in developing economies the impact is likely to be higher. Biofuels, however, can bring benefits to counterbalance some of the potential negative impact through improved market mechanisms and economic development. It must be noted, however, that the costs and benefits may not always fall to the same parts of the population and that local governments and policy makers play a key role in managing the situation.

Increased demand from biofuels has an impact on agricultural commodity prices.

However, several factors could moderate any price increases that may occur. As most crops currently used for biofuels are globally traded commodities, market competition will moderate prices. Technology will continue to play a major role by increasing yields and production and by enabling energy crops and waste to be turned into biofuels. Economic profitability and viability are contingent on continued technological improvements, especially energy use savings to improve energy efficiency in production processes.

The biofuels industry has the potential to create and improve market mechanisms such as physical infrastructure, which can moderate prices. The expansion of the biofuels industry can lead to deflation for selected feeds and foods due to biofuel co-products.

The environmental sustainability of biofuels is described in terms of their implications for energy balance, GHG emissions, biodiversity, water and soil. Reduction of GHG emissions is considered to be the most significant environmental impact. The type of GHG (CO_2, methane, N_2O) depends on agricultural practices (fertilizer use, pesticides, harvesting), the conversion and distribution process, and the final consumption. A biofuel's GHG reduction potential suffers markedly by any conversion of grasslands and forests into agricultural land. The conversion (drainage) of peatlands for increased palm oil production in Malaysia and Indonesia is an extreme example: 2 trillion t/CO_2 may have been emitted in Indonesia since 1997. The carbon debt, the amount of carbon dioxide emitted in the first 50 years as a result of land conversion and land clearance by burning, becomes progressively reduced with time if the bioenergy net GHG emissions are lower than the GHG life-cycle emissions of the fossil energy.

Soil conservation agriculture is increasingly promoted as a best practice for sustainability; however, past adoption rates suggest this occurs at a very slow pace, unless drastic incentives are introduced. Several issues require further research and discussion, including measurement of indirect land-use change, and soil carbon, which vary considerably, depending on site-specific conditions.

Given that one important motivation for bioenergy development is to increase energy security and the need to understand the extent to which biomass is qualified to replace fossil fuels, the notion of fossil energy balance was introduced: the ratio between renewable energy output and fossil energy input needed to produce the biofuel. Comparing different biofuel feedstocks based on their fossil energy balance, palm oil for biodiesel could yield an energy balance even higher than 9.0 (i.e. 9 times the energy required for its production) whereas other oilseeds such as soy and rapeseed have lower energy balances (ranging between 1 and 4) due to the lower yields and the more energy-intense conversion process. Among the ethanol feedstocks, sugar cane may have the highest energy balance, but it displays considerable variation (from 2 to 8). These calculations may not take into account the effect of indirect land-use change.

Biodiversity is recognized as an important factor but there are still no standard ways to measure which systems to promote, except in general terms (such as use of rotations, etc.). Current production systems do not indicate stability or even maintenance of biodiversity. However, biomass production for bioenergy can have both positive and negative impacts on biodiversity: when degraded land is used and if GHG emissions are reduced, the diversity of species might be enhanced while, on the other hand, large monocultures of energy crops can cause habitat loss, the expansion of invasive species, and contamination from fertilizers and herbicides, with concomitant erosion of biodiversity.

TABLE 2.4 - PRINCIPLES AND CRITERIA OF DIFFERENT BIOENERGY CERTIFICATION INITIATIVES

	Roundtable on Sustainable Biofuels	Netherlands/United Kingdom	Germany	European Union	Brazil
Name of certification initiative	**RSB Principles and Criteria Version Zero**	**RTFO Meta-Standard**	**Biomass Sustainability Ordinance**	**Directive on Promotion of Renewable Energy Sources**	**Environmental Directives of Sugar Cane Sector Protocol (Guidelines)**
Legal aspects.	Follow national laws of, and international treaties relevant for, the producing country.	No violation of national laws and regulations that are applicable to biomass production, water management, emissions and air quality.	n.a	n.a	n.a
Principles and criteria					
1. Consultation, Planning and Monitoring	Comprehensive, transparent design; participatory processes with all relevant stakeholders. Planning and monitoring according to scope of the project.	Indirectly mentioned.	n.a	n.a	n.a
2. Climate Change and GHG	GHG emissions reductions compared to fossil fuels; LCA with estimated or default values.	GHG reduction potential of at least 50-70% for electricity; 30% for biofuels LCA methodology with default or actual values.	GHG reduction potential of at least 40% (after 2011) to qualify for quota; LCA (default/ actual values).	GHG reduction of at least 35% (60% after 2017 or 50% with existing production) to qualify for biofuel target - LCA with (default/actual) values.	n.a
3. Carbon Conservation	Direct land use change in GHG estimates Indirect land use change in GHG estimates if possible.	• Production with important carbon sink gains in soil; • Conservation of above-ground (vegetation) carbon sinks; • No biomass production if loss to above-ground carbon (or cannot be recovered within 10 years) (ex: grasslands, peat areas, mangroves and wet areas); • Conservation of underground (soil) carbon sinks when biomass units are installed.	• No cultivation in high carbon stock areas (wetlands; • untouched peatland; • continuously forested areas); • Inclusion of direct land use change; • Monitoring and report obligations on land use change.	• Inclusion of direct land use change in GHG estimates; • Report on indirect land use change by 2010.	n.a

TABLE 2.4 - PRINCIPLES AND CRITERIA OF DIFFERENT BIOENERGY CERTIFICATION INITIATIVES (CONT'D)

	Roundtable on Sustainable Biofuels	Netherlands/United Kingdom	Germany	European Union	Brazil
4. Human and Labour Rights	Non-violation of labour or human rights; Guarantee of decent work for workers: • Freedom to organize; • No slave or child labour; • No discrimination; • Respect minimum wage; • Respect international; Safety and health standards of stakeholders.	Contribute towards social well-being of employees and local population; Non-violation of labour or human rights; No negative effects on workers conditions; Comply with ILO Tripartite Declaration of Principles concerning Multinational Enterprises and Social Policy.	n.a	Report on ratification and implementation of export countries to Conventions of the ILO.	n.a
5. Rural and Social Develop-ment	Contribute to social and economic development of local stakeholders; Should benefit women, youth, indigenous people and vulnerable groups.	Shall contribute towards local prosperity.	n.a	n.a?	n.a
6. Food Security	Shall not impair food security; Promote waste/residues as feedstock; Promote use of degraded; land No displacement of staple crops in food insecure areas.	Must not endanger food supply and local biomass applications (energy supply, medicines, building materials).	Monitoring and report obligations of food price developments.	Report on impact of biofuels on food prices till 2012.	n.a

TABLE 2.4 - PRINCIPLES AND CRITERIA OF DIFFERENT BIOENERGY CERTIFICATION INITIATIVES (CONT'D)

	Roundtable on Sustainable Biofuels	Netherlands/United Kingdom	Germany	European Union	Brazil
7. Soil	Promote practices to improve soil health and minimize degradation; Maintain/enhance health of soil and organic matter; Waste and by-product management shouldn't impair soil health.	Best practices to improve the soil and soil quality: • Prevention and control of erosion and salination; • Conservation of soil nutrient balance and organic matter; • Optimal use of co-products without impairing soil quality; • Compliance with (at least) Stockholm convention (12 most harmful pesticides).	No significant deterioration of soil function/fertility; Good agricultural practices regarding crop rotation, soil`fertilization and plant protection; Environmentally safe fertilizer and chemical use.	Reporting obligations for economic operators on actions aiming at soil protection of soil and restoration of degraded land.	Implement Soil Conservation, erosion control, water runoffs; Adopt good practices for agrochemicals; Promoting triple washing practices; Operators correct training and use of certified protection equipment.
8. Water	Optimize resource use, minimize contamination, or depletion of surface & groundwater; Respect formal and customary water rights. Include water management plan; Maintain/enhance surface and groundwater resources to optimal level.	• No depletion of ground and surface water and maintenance, improvement of water quality; • Best practices must be applied to restrict the use of water and to retain or improve ground and surface water quality; • The production and processing of biomass must not be made of water from non-renewable sources.	No significant deterioration of water quality and water supply.	Reporting obligations for economic operators on actions aiming at protection of water.	Protect the water springs of rural areas of sugar cane farms; Implement Water Resources Conservation; Water Reuse Program.
9. Air	Minimize air pollution from production and processing.	Air quality must be maintained or improved; Best practices must be applied to reduce emissions and air pollution; No burning as part of the installation or management of biomass production units.	No significant increase in emissions of acidic, eutrophic, ozone-depleting or toxic substances.	Reporting obligations for economic operators on actions aiming at protection of air.	Adoption of good practices to minimize air pollution, and reuse of industrial process solid waste; Minimization plans for existing and new bagasse-fired boilers; Accelerated phasing-out of sugarcane crop burning practices; No burning at sugar cane harvest in expansion areas; No burning sugarcane sub-product without a control system.

TABLE 2.4 - PRINCIPLES AND CRITERIA OF DIFFERENT BIOENERGY CERTIFICATION INITIATIVES (CONT'D)

	Roundtable on Sustainable Biofuels	Netherlands/United Kingdom	Germany	European Union	Brazil
10. Land Rights	No violation of land rights and land use rights; Free prior and informed consent on land right relinquishment; Fair compensation for agreed land acquisition; Development of mechanisms to resolve land right disputes	Respect private property rights and customary law; Land use by investors must be transparently described and officially laid down.	n.a	Report addressing the issue of land use rights till 2012.	n.a
11. Conservation and Biodiversity	Avoid negative impacts on biodiversity: • Ecosystems, and areas of high conservation value; • Creation/protection of buffer zones; • Protection/restoration of ecological corridors.	Maintenance and enhancement of biodiversity; No feedstock production in protected, high conservation gazetted areas (grandfathering clause), or close to those areas; Maintenance or recovery of biodiversity in new or recent developments within the production units; Good practices to strengthen biodiversity in ecological corridors and prevent damage as much as possible.	No cultivation of feedstock in areas with high biodiversity value.	No cultivation of feedstock in areas with high biodiversity value as long as it is not in conformity with protection objectives	Protect the Riparian Forest
Source:	RSB, 2008b	RFA, 2009b	BMU, 2007	EP, 2008b	Etanolverde, 2009

Key considerations in local biomass development are water availability and fertilizer use. In many situations, water can be an even more essential factor than carbon to consider in determining sustainability. Both the quantity of water used and impact on local water quality may, in some cases, prevent the establishment of a biorefinery. Fertilizer runoff into streams and rivers contributes to eutrophication. Chemical fertilizer use could be lowered if crop and forest residues can be used for soil nutrient management.

Three methods to measure environmental sustainability were outlined in this chapter: Life Cycle Assessments, Land-use Change Methods, and Local Environmental Impact Assessments. Social sustainability is described in terms of land ownership rights, local stewardship of Common Property Resources and effects on the labour force, with reference to the existence of ILO Conventions and use of the Social Impact Assessment as a tool to measure social sustainability. Life cycle analyses are increasing within the literature and these form a good basis for comparing various biomass-biofuel systems but methods are still not standardized and still suffer from lack of full accounting of indirect land-use change.

In the context of the above issues, attention was focused on initiatives on bioenergy sustainability undertaken by certain countries, and the legislative landscape for those initiatives. Broadly speaking, most of the initiatives on biofuel sustainability are from industrialized economies where the potential growth of the biofuel sector is virtually unlimited given the scope for energy consumption substitution. This is particularly the case in Europe and North America. Consequently, for these economies, the types of sustainability criteria targeted reflect the combined effect of a set of drivers that include ensuring greater domestic energy supply (and protection of domestic bioenergy industry); safeguarding the existing protections to domestic agriculture; responding to consumers and environmental groups and concerns; and finally acting on their climate change mitigation goals in terms of reductions in GHG emissions.

Because the EU (more than North America) as a whole depends relatively more on imported biomass and feedstocks, its regulations and voluntary standards on sustainability are outward-looking, tailored to specific key biomass-biofuel export sources (e.g. Argentina, Brazil, Indonesia and Malaysia). As a whole, the EU sustainability system is a combination of enforceable directives combined with a set of private sector-driven voluntary sustainability schemes to enforce the directives. The USA and Canada are by contrast largely domestically focused, and in the case of the USA, the key sustainability target is the new GHG reduction requirement for advanced biofuels, while all other sustainability criteria are left to the private sector to address through voluntary standards and schemes under the aegis of the Council on Sustainable Biomass Production.

The developing export-oriented countries (such as Brazil, Indonesia and Malaysia) are also concerned about implementing sustainability criteria for feedstock and biofuel production, largely to access the huge industrial markets of Europe and North America. Other big developing countries, such as China and India, seem to have different priorities such as avoiding using food as feedstock. One international mechanism that could support other developing countries' engagement along biofuel sustainability is the GBEP, which serves as an intergovernmental forum for promoting the transformation of biomass use towards more efficient and sustainable practices based on exchange of skills and technologies.

The issues of biofuel production are challenging in technical, political and economic terms. As food prices rose in 2007/08 and scientists started to question the environmental superiority of biofuels, the debate ignited on how to approach sustainability in practice. One solution may be the introduction of standards and certification schemes. The following chapter will consider different initiatives that have been outlined by the public and private sectors. Starting in 2011, a number of feedstock-specific standards have started certifying and tracing products. The next chapter offers an analysis of the main sustainability schemes, evaluates their strengths and shortcomings and assesses the scope of wider applications.

Many national, intergovernmental and multistakeholder initiatives are trying to grapple with the complex and intertwined dimensions of sustainability. At the same time, these initiatives also raise a number of thorny questions that still need to be addressed. Among these is the question of whether "voluntary standards" for sustainability are sufficient to address the real challenges of sustainable growth. Another question is how to design standards so as to avoid differential treatment of domestic vs imported biofuels. For example, lack of efficiency of subsidies for GHG savings indicates domestic industry motives are having an effect (i.e. energy security may still drive biofuel domestic policies) even though climate change is becoming a more serious consideration. Sustainability standards currently proposed are still works in progress given the lack of reliable criteria and indicators to "measure" and quantify sustainability on the ground. Finally, many published standards, criteria and indicators (e.g. RSB) are still too generic and have not yet been proven to be workable under specific local conditions.

Chapter 3

A review of biofuel certification schemes and lessons for sustainability

3.1 Introduction

Ensuring a sustainable feedstock-biofuel system entails an integrated, holistic assessment of the economic, environmental and social dimensions. An increasing number of sustainability initiatives have emerged in recent years, many of which are implemented through certification schemes. The sustainability initiatives, reviewed in Chapter 2, reveal a wide range of issues to tackle along the three core sustainability dimensions (i.e.. economic, environmental and social). Consequently, the certification schemes developed to address sustainability concerns differ widely in terms of scope and coverage, including GHG emissions reduction, biodiversity preservation, land-use changes, food security and social well-being.

Certification is an attestation (i.e., issue of a statement) by a third-party that specifies that requirements related to products, processes, systems or persons have been fulfilled (ISO).[17] A certification body is a legal or administrative entity that has specific tasks and composition, with acknowledged authority for publishing standards.[18] Certification schemes are based on a set of principles and criteria and are meant to ensure that bioenergy is sustainably produced, processed and transported. The standards or certificates give buyers – governments, businesses or individual consumers – a means of differentiating among products.

A certification scheme is defined as the process that ensures that sustainability standards are met. The requirements can vary from one single criterion or product/ process to a range of criteria along the whole life cycle from the field to the consumer. The main function of the certificate is to signal to the purchaser that the product complies with certain qualities or that the production process follow specified procedures. To be effective, certification schemes rely on successful traceability, i.e. a reliable means to track inputs through the supply chain in order to determine if production is really sustainable. Typically, the certification process is handled by a specialized certification agency – a third-party intermediary between buyers who demand certification and sellers who comply with it. To oversee the work of

[17] Adapted from ISO/IEC 17000, 2005, Definitions 5.2 and 5.5). See: http://www.iso.org/sites/ConsumersStandards/en/5-glossary-terms.htm

[18] Adapted from ISO 17000 and ISO/IEC Guide 2 for definitions of "recognition" and "body". See: http://www.iso.org/sites/ConsumersStandards/en/5-glossary-terms.htm

certification agencies and to monitor and assess the entire process, there is also an accreditation body, which can be an NGO or a governmental or semi-autonomous entity integrated within the agency (Woods and Diaz-Chavez, 2007).

There are costs involved in the production and supply of certified biofuels, including compliance, certification and opportunity costs. More significant are the certification compliance costs which require that the production process is realigned to meet the sustainability criteria underlying the certification. However, any effort to quantify the magnitude of these costs (e.g. compliance, certification) has to be done on a case-by-case basis. The broad factors likely to affect the overall cost of biofuel certification can be grouped into the following categories: (i) compliance criteria; (ii) choice of feedstock and other primary production factors (e.g. land, labour); (iii) changes in management practices (i.e. deviation from existing practices); (iv) amount of fixed costs required; and (v) certification costs.

In this chapter, we provide a critical review of the biofuel certification schemes and assess their effectiveness in terms of achieving sustainability criteria. This review will also include other non-biofuel certification schemes, such as organic agriculture and forest management, and draw lessons for applicability to biofuels and biomass certification. Also, biofuels certification schemes will be evaluated from the perspectives of implementation cost, ease of applicability, effectiveness of enforcement and inclusiveness of small-scale farmers within the biofuel supply chains, especially in developing countries.

3.2 Examples and lessons from certification schemes

3.2.1 Forestry

There are a number of forest certification schemes that cover many aspects of sustainable biofuels production. One of the first was the **Forest Stewardship Council (FSC)** founded in 1993. The FSC is an independent, non-governmental, non-profit organization established to promote responsible forest management in response to concerns about deforestation and poor management of forest resources. It provides standard setting, trademark assurance and accreditation services for companies and organizations interested in responsible forestry, linking responsible production and consumption of forest products.

The FSC Principles and Criteria describe how forests are to be managed in order to meet the social, economic, ecological, cultural and spiritual needs of present and future generations, which include managerial, environmental and social requirements. Ten principles and 56 criteria form the basis for all FSC forest management standards, which are then further defined and explained by policies.

Criteria involve social, silvicultural, environmental and economic issues. For example, the conversion of natural forests is prohibited, as is the use of perilous pesticides and Genetically Modified Organisms (GMOs). Moreover, the rights of local populations are explicitly highlighted

As of June 2012, 23 439 certificates have been issued for a total of 107 countries. Approximately 850 individuals and organizations are members of the FSC. These include environmental and social organizations, indigenous communities, forest owners, wood- and paper-working companies, retailers, researchers, technicians and many others – and about 60 National Initiatives in different countries (FSC, 2012).

The Programme for the Endorsement of Forest Certification schemes (PEFC) was founded in 1999. It is a non-profit international umbrella organization based on inter-governmental conventions. A wide range of products are included, both forest products (such as timber and paper) and non-wood forest products (such as agricultural fibre and berries). It has 25 fully recognized national schemes and ten more that are in the process of being accepted. Some of the largest programmes endorsed in the PEFC programme are the North American **Sustainable Forest Initiative (SFI)**, the **Australian Forestry Standard (AFS)**, the **Brazilian Programme of Forest Certification (CERFLOR)**, and **Chile Forest Certification Corporation (Certfor)** (PEFC, 2009). As of June 2012, 243 million ha of forest were certified within the programme, and around 8 500 companies and organizations have achieved PEFC Chain of Custody certification, making PEFC the largest forest certification system in the world.[19] Unlike FSC, PEFC does not have its own accreditation body but relies on national accreditation services. Some NGOs have criticized that this practice could lead to less control over the certified companies and that in some cases forests have been certified although unsustainable logging practices in sensitive areas are taking place (Roberts, 2007).

3.2.2 Agriculture

There are also a substantial number of organizations focusing on sustainable agriculture. The **Sustainable Agriculture Network (SAN),** for example, is headed by the **Rainforest Alliance** with the aim to improve sustainable cultivation of over 100 crops. Criteria involve social and environmental aspects as well as guidelines for sustainable farm management.

The SAN is a coalition of leading conservation groups that links responsible farmers with conscientious consumers by means of the Rainforest Alliance Certified™ seal of approval. Its collective vision is based on the concept of sustainability, recognizing that the well-being of societies and ecosystems is dependent on development that is environmentally sound, socially equitable and economically viable. The SAN develops, manages and owns the Sustainable Agriculture Standard.

The SAN currently includes environmental groups in Brazil, Colombia, Costa Rica, Ecuador, El Salvador, Guatemala, Honduras, India, and Mexico, with many associated academic, agriculture and social responsibility groups around the world. SAN seeks to transform the environmental and social conditions of agriculture through the implementation of sustainable farming practices. The conservation and rural development groups that manage the certification programme understand local culture, politics, language and ecology and are trained in auditing procedures according to internationally recognized guidelines.

Certification by SAN for farms that want to become Rainforest Alliance Certified™ is currently offered by an independent international certification company, responsible for granting farm certification against the Sustainable Agriculture Network Standards.[20]

Focus has been on developing countries and on products such as coffee, tea, cocoa, flowers and fruit. Additional criteria have been added for typical biofuel crops: oil palm, sugar cane, soy, peanut and sunflower. For these feedstocks GHG emissions, energy balances and the diminution of cane burning are also included (Bach, 2009).

The Roundtable on Sustainable Palm Oil (RSPO) is a multi-stakeholder initiative established in 2003. The first sustainable palm oil producers were certified in 2008. The RSPO developed Principles and Criteria on Sustainable Palm Oil Production

[19] See PEFC Web site: www.pefc.org.

[20] Through their web page: http://www.sustainablefarmcert.com/certified_farms.cfm it is possible to find requirements and processes for certification, along with the existing certified farms, searching by crop and country.

to ensure that palm oil production is economically viable, environmentally appropriate and socially beneficial.

RSPO seeks to promote projects such as:

- plantation management practices – implementation of better management practices (BMPs) in existing plantations;
- development of new plantations – improvement in land-use planning processes for the development of new oil palm plantations;
- responsible investment in oil palm – improvement of risk analysis/ decision-making tools for banks and investors on palm oil development; and
- chain of custody – investigation of different approaches for creating links between the oil palm plantations and the consumer.

The system of criteria and principles already covers many of those suggested by the **Roundtable on Sustainable Biofuels** (RSB). Nevertheless, criteria concerning land use and food security, GMO and GHG emissions are not addressed (Fehrenbach et al., 2008).

By 2011, the estimated annual production capacity of RSPO-certified production units – 4.2 million tonnes of sustainable palm oil – was about 9 percent of global production, estimated to be about 46 million tonnes annually. RSPO-certified palm oil production facilities produced their five-millionth tonne of certified sustainable palm oil in May 2011. As of April 2012, 56 licences were issued, including five growers and one supply chain of custody company.

About 54 percent of the world's current RSPO-certified palm oil production capacity is in Malaysia. Indonesia is second, producing about 35 percent of the current global supply. Papua New Guinea and Colombia provide the remaining 10 percent and 1 percent, respectively.

Other than palm oil, certified mills also collect palm kernels for further processing. At present, certified production units harvest close to 1 million tonnes of palm kernels annually, out of which about 450 000 tonnes of RSPO-certified sustainable palm kernel oil and derivatives will be processed. If palm oil production increases to 48.3 million tonnes by 2012 (OECD/FAO projection, 2009), this would mean a share of RSPO-certified oil in total palm oil of 15.5 percent.[21] According to the World Wildlife Fund (WWF), a small percentage of the certified amount had been purchased. RSPO ascribed the slow start to the economic crisis and the unwillingness of large companies to pay the price premium (Fogarty, 2009). The amount is expected to rise to 7.5 million tonnes in 2012 (Fehrenbach et al., 2009).

As of June 2011 approximately 24 growers and 100 mills have been certified. Regarding the whole supply-chain certification, around 81 companies and 147 facilities have been certified to this date. Through the RSPO Web page there is a link to the Online Market Centre where traders, manufacturers and retailers are able to sell, buy or use (redeem) certificates. (RSPO FAQs & factsheets)

The **Roundtable on Responsible Soy (RTRS)** is the global platform composed of the main soy value-chain stakeholders with the common objective of promoting a multistakeholder-defined (i.e. industry, producers and NGOs) set of voluntary sustainability criteria for soybeans. The RTRS standard became fully operational in 2010. Overall, the standard is structured into 21 criteria, including relevant indicators, which are designed around the following five principles:

[21] Source: Green Palm certification: http://www.greenpalm.org/en/blog-press/blog/rspo-certified-production-passes-5-million-tonnes-mark.

- legal Compliance and Good Business Practice;
- responsible Labour Conditions;
- responsible Community Relations;
- environmental Responsibility;
- good Agricultural Practice.

Additional requirements specific to the European Union RED include GHG reduction, land use and carbon savings. As of January 2012, there are ten certified producers and four certified chain of custody companies.[22]

Another key feedstock for the production of biofuels is sugar cane. The **Bonsucro (former Better Sugar Cane Initiative)** is "a global multistakeholder [sugar retailers, investors, traders, producers and NGOs] association established to reduce the environmental and social impacts of sugar cane, by designing a standard and programme to transform the sugar cane industry." The Bonsucro Standard incorporates a set of Principles, Criteria, Indicators and Verifiers which will be used to certify sugar producers who comply and to guide companies in the sugar and ethanol value chain who wish to procure sustainable feedstock supplies, and also those in the financial sector who wish to make more sustainable investments.

The standard is based on a set of metric measurements which allows for aggregation, and a clearer demonstration of impact. The unit of certification will be the sugar mill and audits will be based on assessments of the mill and cane supply area. Accredited auditors will be required to conduct the evaluations.

Bonsucro aims, in particular, to:

- define globally applicable performance- based principles, criteria, indicators and standards for sugar cane production;
- promote measurable improvements in the key economic, environmental and social impacts of sugar cane production and primary processing; and
- develop a certification system that enables producers, buyers and others involved in sugar and ethanol businesses to obtain products derived from sugar cane that have been produced according to agreed, credible, transparent and measurable criteria.

In 2008, Bonsucro established three Technical Working Groups (TWGs) to identify indicators that can be measured, which allow an assessment to be made of whether or not associated criteria are being met. Expert groups covered the three areas of:

- social and labour;
- processing and milling;
- agronomic practices.

Bonsucro members agreed to develop criteria and indicators around the following five principles:

- obey the law;
- respect human rights and labour standards;
- manage input, production and processing efficiencies to enhance sustainability;
- actively manage biodiversity and ecosystem services; and
- continuously improve key areas of the business.

In order to obtain certification, producers must achieve 80 percent compliance with the indicators contained in these principles. Furthermore, a set of core criteria must be met before compliance can be considered, namely:

- comply with relevant applicable laws;
- comply with ILO labour conventions governing child labour, forced labour, discrimination and freedom of association, and the right to collective bargaining;

[22] See the RTRS Web site: http://www.responsiblesoy.org/

- provide employees and workers (including migrant, seasonal and other contract labour) with at least the national minimum wage;
- assess impacts of sugar cane enterprises on biodiversity and ecosystems services; and
- ensure transparent, consultative and participatory processes for greenfield expansion or new sugar cane projects that address cumulative and induced effects via an environmental and social impact assessment (ESIA).

Producers must also achieve 80 percent compliance with the criteria contained in the Chain of Custody Section. For the production of ethanol intended to be put on the European Union market and application for the Bonsucro EU Certification, producers are required to satisfy full compliance of additional requirements in the Section related to Additional Mandatory Requirement for biofuels under the EU Renewable Energy Directive (2009/28/EC) and revised Fuel Quality Directive (2009/30/EC).

The Bonsucro certificate effectively started in 2010, and as of June 2012, 14 mills and six chain of custody companies were certified.[23]

The **International Federation of Organic Agriculture Movements (IFOAM)** is a consortium of suppliers, NGOs, certification bodies and other stakeholders to encourage organic farming. IFOAM is a member of the International Social and Environmental Accreditation and Labelling Alliance (ISEAL); it is through ISEAL membership that IFOAM promotes and supports private systems for labelling of ecological and socially sustainable methods of production, which include organic agriculture. The organic principles are based on four pillars: health, ecology, fairness and care. In practice, this translates into rather high environmental standards (e.g. regarding the use of agro-chemicals, fertilizers, etc.) as well as labour rights. The environmental criteria are generally more comprehensive for organic farming than most bioenergy certification schemes require, while other important criteria (e.g. land use change and GHG emissions) are missing. Even so, organic certification could become an important basis for biofuel certification further down in the value chain. There are a number of organizations certifying organic produce (to mention a few: Demeter International, US California Certified Organic Farmers [CCOF] and Australian Certified Organic).

The **International Social and Environmental Accreditation and Labelling Alliance (ISEAL)** is the global association for social and environmental standards systems. ISEAL members are leaders in the field, committed to creating solid and credible standards systems. Working with established and emerging voluntary standards initiatives, ISEAL develops, guides and facilitates coordinated efforts to ensure their effectiveness and credibility and to scale up their impacts. ISEAL's Codes of Good Practice are international reference documents for credible social and environmental standards. Compliance is a membership condition. (www.isealalliance.org)

ISEAL member organizations[24] promote a healthier environment and better social and economic conditions for producers and their communities through the implementation of international standard setting, certification and accreditation

23 See the Bonsucro Web site: http://www.bonsucro.com/certified_members.html

24 Founding Members of ISEAL (2002): Fairtrade Labelling Organizations International (FLO); Forest Stewardship Council (FSC); International Federation of Organic Agriculture Movements (IFOAM); International Organic Accreditation Service (IOAS); Marine Aquarium Council (MAC); Marine Stewardship Council (MSC); Rainforest Alliance; Social Accountability International (SAI).

systems that comply with internationally accepted criteria, encompassing sustainable agriculture, fair trade and humane labour standards. They are all characterized by a concern for human rights, sustainable livelihoods and environmental health. In all cases certification standards are based on the process or production methods used in the development or harvesting of products, rather than on characteristics of the end product itself.

3.2.3 Biofuels

An increasing number of biofuel certification schemes have emerged in recent years, largely as the result of EU regulations but also out of concern that biofuel expansion may generate its own undesirable sustainability consequences.

An example of early biofuel certificates is the Green Gold Label (GGL) programme – a certification system for sustainable biomass that covers production, processing, transport and final energy transformation. According to its Web site, the GGL provides standards for specific parts of the supply chain, as well as standards for tracking and tracing the origin of the biomass. The GGL has been operational since 2002 as the global certificate for sustainable biomass, and is a leading accredited certification system – more than 5 million tonnes of biomass have been certified with the GGL over nine years. GGL is committed to supporting the development of sustainable biomass for energy, power production and chemical purposes. Currently over 25 biomass suppliers are GGL-certified producers/ traders, as verified by Control Union Certifications, an accredited certification body. Table 3.1 provides the list of principles and criteria required to meet the GGL.

Another early example is the Swedish "**Verified Sustainable Ethanol Initiative**" run by the Swedish energy company SEKAB together with the Brazilian ethanol producers who started the initiative in 2008. Under this system, an independent international company does the onsite auditing and checks to make sure the producers are meeting the system's requirements. The initiative requires that sugar cane ethanol comply with a list of sustainability criteria in environment, climate, social and ethical aspects, including generating lower fossil carbon-dioxide emissions than petrol and diesel. The main sustainability criteria are summarized in Table 3.2.

The initiative is the result of an understanding between the Swedish trade association BioAlcohol Fuel Foundation (BAFF) and UNICA, the Brazil sugar cane industry representative, to jointly drive the process towards more sustainable bioethanol production. As such, the SEKAB-verified Sustainable Ethanol Initiative is among the first operational certification schemes for biofuels.

In the United Kingdom, fuel sustainability considerations trace back to the Renewable Transport Fuels Obligation (RTFO). Compliance with RTFO induced several certification schemes. **Greenergy,** for example, has introduced sustainability criteria for its imports of Brazilian ethanol that met the "Gold Standard" in January 2009 (RFA, 2009a). They also refrain from buying ethanol made from US corn and oil palm produced on peat land.[25]

One of the most noticeable transnational biofuel-specific schemes is the **Roundtable on Sustainable Biofuels (RSB)**, an international, multistakeholder initiative that was established in 2006 to achieve global consensus around a set of principles and criteria for sustainable liquid biofuel feedstock production, processing and biofuel transportation/distribution.

[25] For more information, see Greenergy, 2009 and RTFO).

TABLE 3.1 - GREEN GOLD LABEL PROGRAM (VERSION 2010)

Principles	Criteria	
1. The agriculture management system is part of an integrated long term planning program (either individually or organized in a group), aimed at development and sustainability	1.1	A long term commitment to adhere to principles and criteria for sustainable agriculture: updatable agriculture management plan
	1.2	Policy reviews are carried out periodically
	1.3	A policy is implemented to influence tenure and property rights of local smallholders positively, with respect to the minimum size of land-holding
	1.4	The management plan addresses policy on improving production, harvesting, storage, processing, distribution and marketing of products on local, national and regional level
	1.5	Storage and distribution problems, affecting food availability are identified and dealt with in the manaagement plan
2. The agriculture management system is based on land-resource planning	2.1	Data collection and continuous monitoring of utilization of natural resources and living conditions are used for the land resource planning (individually or on a regional basis)
	2.2	Participation in the initiation and maintenance of district and village agricultural land resource planning assisted by management and conservation groups
3. The agriculture management is aimed at land conservation and rehabilitation	3.1	Land degradation is surveyed on a regular basis
	3.2	Land and conservation areas at risk are identified and the policy and management measures are formulated
	3.3	The general planning, management and utilization of land resources and the preservation of soil fertility are defined and executed
4. The agriculture management is aimed at the insurance of freshwater supply and quality for sustainable food production and sisstainable rural development	4.1	Efficiency and productivity of agricultural water use for better utilization of limited water resources has to increase
	4.2	Monitoring of the irrigation performance
	4.3	Proper dispose of sewage and waste from the farm and human settlements and of manure produces by intensive livestock breeding
	4.4	Water quality has to be monitored on biological, physical and chemical quality
	4.5	Measures have to be taken to minimize soil run-of and sedimentation
	4.6	Irrigation has to be planned in a long term program
	4.7	Long term strategies and implementation program have to be developed on water use under scarce conditions
	4.8	Waste water re-use has to be part of the agriculture management system
5. The agricultural management system has implemented integrated pest management and control	5.1	The management system is based on an integrated system of pest control
	5.2	The use of banned pesticides is prohibited
	5.3	The use of restricted pesticides is controlled and administration is kept up to date
	5.4	Biological control agents, organic pestices and non-chemical traditional knowledge for pest control to be identified/implemented in the agriculture management system
6. The agricultural management system has implemented sustainable plant nutrition to increase food production	6.1	The management plan is based on an integrated plant nutrition approach
	6.2	The availability of fertilizer and other plant nutrient resources are optimized
7. Raw materials shall not be obtained from land with high biodiversity value	7.1	The raw material is not produced on land that is primary forest, for nature conservation, or with highly diverse grasslands and non-grasslands
8. Raw materials shall not be obtained from land with high carbon stock	8.1	The raw material is not produced from land with high carbon stock (continuously forested areas; wetlands, lands with trees above 5 metres)
9. Raw materials shall not be obtained from peatland	9.1	Raw material not produced from peatland except if soil is completed drained since 2008
10. Agricultural raw materials cultivated in the community shall be obtained in accordance with the European "Cross Compliance" regulations	10.1	Agricultural raw materials cultivated in the Community must comply with the requirements and standards under the provisions refered to under the heading "Environment" in part A of Annex III to Council Regulation (EC No 1782/2003)

TABLE 3.2 - CRITERIA FOR THE SEKAB-VERIFIED SUSTAINABLE ETHANOL INITIATIVE

Criteria	Criteria specifics
GHG reduction	At least 85 percent reduction in fossil carbon dioxide compared with petrol, from a well-to-wheel perspective using calculations according to RTFO principles, defining fossil input to include fertilizers, pesticides and fossil energy; and defining renewable output to include ethanol and energy (e.g. steam, electricity)
Harvest mechanization	At least 30 percent mechanization of the harvest now, plus a planned increase in the degree of mechanization to 100 percent; this would lower local particle emissions and improve CO_2 emissions
Deforestation	Zero tolerance for felling of rain forest; i.e. no deforestation of rain forest and deforestation of other forests to be carried out according to national laws which require permits and tree replanting requirements for downed trees;
Child labour	Zero tolerance for child labour below 16 years of age and hiring apprentices above 14 years and in compliance with article 1 and 2 of ILO convention 138
Employees' rights	Rights and safety measures for all employees in accordance with UN guidelines; this include zero tolerance for forced labour ("slave labour"); workers' right to organize in unions is protected; all employees must be registered and must be paid at least minimum wages; health and safety policies must be followed
Biodiversity	Ecological consideration in accordance with UNICA's environmental initiative, including protection of forests close to water areas, protection of water resources, reuse of water in industrial processes, conservation of water quality, implementation of plan for soil conservation
Monitoring	Continuous monitoring that the criteria are being met through audits by an independent third party, and no-compliance to be corrected before next audit, minor non-compliance to be corrected within three months, while major non-compliance requires a mitigation plan to be submitted within 14 days of audit and a scheduling of an extra audit.
Traceability	Full traceability of all physical flows

The RSB standard focuses on the following set of criteria:

- the GHG performance through the whole life cycle of biofuels;
- biodiversity and ecosystem services;
- soil, water and air quality;
- local development and food security; and
- land rights, water rights and stake-holder engagement.

The RSB standard is applicable to any crop in any country and the certification model is based on a risk management approach, which adjusts the audit requirements to the risk class of the operator. The RSB identifies four types of operators, each subject to different set of requirements: (i) feedstock producers; (ii) feedstock processors; (iii) biofuel producers; and (iv) blenders.

The criteria included in Version 2 of the RSB Standard address only the direct activities that farmers and producers can undertake to prevent unintended consequences from biofuel production. When Version 1 was at the point of approval, the RSB methodology for calculation of life cycle GHG was still under development; consensus among a panel of experts arrived at an agreed methodology to be included in RSB Version 2.

The RSB certification was launched in March 2011. As of December 2011, one ethanol company from Australia was certified under RSB.

The **ISCC (International Sustainability and Carbon Certification)** is another government-supported, private-run scheme from Germany. The ISCC system is a certification system for sustainable biomass and biofuels operated by Meo Company. The ISCC is the first system approved by the Government of Germany. It has been approved by the German

Authority BLE as the first certification system for sustainable biomass and biofuels according to the German Biokraftstoff-Nachhaltigkeitsverordnung (Biokraft-NachV). The ISCC certification system is supported by the German Federal Ministry of Food, Agriculture and Consumer Protection via the Agency for Renewable Resources (FNR).

ISCC is a certification system for biomass and biofuels that describes the rules and procedures for certification and focuses on the reduction of GHG emission, sustainable use of land, protection of natural biospheres and selected social concerns. It does not issue certificates; that is the job of the certifying bodies which are approved by the BLE and cooperate with the ISCC.[26]

The ISCC concentrates on six principles for sustainability requirements for biomass production:

- biomass shall not be produced on land with high biodiversity value or high carbon stock and not from peat land. High carbon value areas shall be protected;
- biomass shall be produced in an environmentally responsible way. This includes the protection of soil, water and air and the application of Good Agricultural Practices;
- safe working conditions shall be provided through training and education, use of protective clothing, and proper and timely assistance in the event of accidents;
- biomass production shall not violate human rights labour rights or land rights. It shall promote responsible labour conditions and workers' health, safety and welfare and shall be based on responsible community relations;
- biomass production shall take place in compliance with all applicable regional and national laws and shall follow relevant international treaties;
- good management practices shall be implemented.

The ISCC certification criteria fall into three categories:

- sustainability requirements for biomass production;
- requirements concerning the GHG emission savings and the associated calculation methodology; and
- requirements for traceability and mass-balance calculation methodology.

A set of "major" and "minor" required criteria was developed around the six principles. For a successful audit, all of the former and at least 80 percent of the latter must be met by the operators along the bioenergy supply chain. The crops and regions considered initially are: wheat and corn in Europe; sugar beet in Europe; rapeseed in Europe; sugar cane in Brazil; soy in Brazil and Argentina; and palm in Malaysia and Indonesia. The meta-standard is open for direct application by producers as well as for endorsement by established certification systems.

The German Government relies on these certification schemes to determine tax reduction eligibility for biofuels. Eligible certified biofuels are deemed "sustainable" if it is demonstrated that the land where the biomass is produced is cultivated sustainably to safeguard natural habitats, where minimum GHG emissions are at least 40 percent lower than with fossil energy (after 1 January 2011).

3.2.4 Sustainability scorecards

Beside criteria and indicators, there are also sustainability scorecards (SS) applied at the project level and prior to approval by international development banks such

26 For a list of approved certifying bodies see: http://www.iscc-system.org/certification_bodies/recognized_cbs/index_eng.html

Box 3.1: Biofuel certification schemes: Are smallholders left behind?

A major challenge in implementing certification schemes is whether small-scale farmers are included or left out by virtue of the design of these schemes and their governance structures. As most biofuel certificates (or standards or roundtables) are voluntary and led by private industry, many NGOS are concerned that they may not offer equal opportunity for small-scale producers who are left out because of financial and technical barriers.

In a study commissioned by FAO to look at small-farmer inclusion into existing certification schemes, three cases were compared from three countries, feedstocks and certification schemes (Sugar cane-ISCC, Peru; Jatropha-RSB, Mali; and oil palm-RSPO, Thailand) (FAO, 2011c). All cases confirmed the lack of current incentives for small farmers to achieve certification and therefore integrate the biofuel certified market. The only way small farmers can still participate in biofuel value chains is because of the allowance of including non-certified products along with certified feedstock/biofuels under a chain system known as mass balance chain of custody which doesn't require strict traceability and strict separation of certified and non-certified products.

Such concerns are real enough that major commodity roundtables have started to take remedial action. The RSPO responded by establishing a special task force to develop sustainability indicators and procedures that are accessible and relevant to smallholders. An effort by RSPO to certify a number of small family farms from Indonesia, Malaysia and Papua Guinea revealed that government assistance and private partnerships among producers are essential to overcome the technical and financial barriers facing smallholders. This experience by RSPO was extended to soybeans (Soy Producer Support Initiative), sugar cane (Sugar Producer Support Initiative) and palm oil (Palm Oil Producer Support Initiative) (Solidaridad, 2011). These initiatives have initiated pilot testing for smallholder compliance with certification schemes such as the Roundtable on Sustainable Biofuels (RSB).

The first hurdle facing smallholders is the financial barrier represented by added certification costs. These costs can be divided among compliance costs, transaction costs and opportunity costs. Compliance costs may involve integrated pest management; replacement of child by adult labour; and training. Transaction costs include fees to third-party inspection, administrative changes for the certificates and administrative costs for smallholders. Opportunity costs arise when adoption of alternative production techniques (e.g. less fertilizer) may lower productivity and hence result in small margins (Huay Lee et al., 2011). A self-sustaining means of meeting these added costs is a big challenge for small-scale farmers unless participation in certification schemes opens up new market outlets and ensures increased revenues.

Another key concern is technical barriers and the need for capacity building for small-scale farmers, many of whom may be called to significantly alter their customary practices and management techniques. Adopting new and sustainable practices may require a new set of skills and capacity. One solution is for farmers to form groups, cooperatives or associations to better harness the new capacity and opportunities. The importance of producers' groups is critical, but may also be challenging for smallholders, especially if there is heterogeneity among producers in terms of wealth, size and quality of land, access to labour and educational

Box 3.1 (*Cont'd*)

background. However, groups, organizations or producers' groups may be the only way for small-scale farmers to meet certification costs and to effectively participate in the economic opportunities afforded by being involved in a sustainable biofuel programme. A number of FSC-certified smallholder cooperatives illustrate this point and show that collective action through producers' organizations ensures efficient dissemination of new information and skills development.

Beyond the immediate benefits of participating in certification schemes – such as easy access to international markets, entering a niche market and receiving higher prices – there are also benefits in the longer run, such as building significant institutional capacity including administrative skills, better quality control and marketing and negotiating skills (Huay Lee et al., 2011). However, producers' organizations, especially cooperatives, must be self-run and operate independently of state interference to avoid the failed examples of cooperatives of the past, especially in commodities like coffee and cocoa. The failure of these has left a bad impression among small-scale farmers in many African countries (Nieslon, 2008).

Finally, to ensure more sustainable and far-reaching inclusion of smallholders in biofuel certification schemes and to expand the potential benefit to small-scale producers, there must be more inclusive and active participation of representatives of smallholder producers' organizations in biofuel roundtables. This would ensure that certification and sustainability roundtables and schemes are led by the private sector and multiple stakeholders.

as the Inter-American Development Bank (IDB). These SS are applied during project development, project screening, initial analysis, due diligence and investment approvals. The main SS in use currently are the **Inter-American Development Bank Sustainability Scorecard** and the **WB/WWF Biofuels Environmental Sustainability Scorecard.**

Inter-American Development Bank (IDB) Sustainability scorecard

The Sustainable Energy and Climate Change Initiative (SECCI) and the Structured and Corporate Finance Department (SCF) of the IDB created the **IDB Biofuels Sustainability Scorecard** based on the sustainability criteria of the Roundtable on Sustainable Biofuels (RSB).

The main objective of the Scorecard is to encourage higher levels of sustainability in biofuel projects, by providing a tool for considering the range of complex issues associated with biofuel production from the field to the tank. The Scorecard has been designed to be useful for different types of biofuels and feedstocks, and includes general, environmental and social criteria. It proceeds from general to more specific information, through the cultivation, production and distribution stages of biofuel production. Table 3.3 provides a checklist to fill out for the Scorecard. The Scorecard will not provide a final score, but rather generates a colour map (ranging from bright green/excellent to red/unsatisfactory) so that the user can see performance across different areas and have a better idea of areas and elements

TABLE 3.3 - IDB SCORECARD LIST

Environmental	Social
PROJECT SITE	
Biodiversity	
No conservation value	Complies with best practices
Moderate conservation value	Complies with basic principles
Natural habitat	Potential violation of human rights
Critical natural habitat	Violation of human rights
Insufficient data	**Labour rights**
Invasive species	Meets or exceeds international standards
Native	Exceeds national standards
Non-native	Meets national standards
Invasive	Informal employment
Domesticated	Violation of labour rights
n.a.	**Land ownership**
Carbon emissions from land use change	Community-based/coop
No land for cultivation	Community involvement as shareholders
Degraded land	Leasing of the land
Cropland	Concentrated ownership
Woody savannah	Displacement with proper compenstion
Forest land	Disputed land
FEEDSTOCK/CROP MANAGEMENT	Involuntary displacement
Crop lifecycle	Involuntary displacement from indigenous territory
Permanent crop	**Change in access to resources**
Multi-year/perennial crop	No change in access to resources
Annual crop	Limited changes in access to resources
No till	Moderate changes in access to resources
Low till	Significant changes with mitigation measures
Crop rotation/crop mix	Significant changes without mitigation
Tilling	**Impact on food security**
Crop rotation and inter-cropping	Positive impact on food security
Crop rotation	No impact on food security
Inter-cropping	Negative impact on food security
No crop rotation or inter-cropping	**Consultation and transparency**
n.a.	Full transparent consultation
Harvesting method	Good faith negotiations and broad community support
No burning	Partial consultation
Field burning	No consultation
Field burning when mechanical harvesting feasible	**Capacity building**
n.a.	Full training plus capacity building programmes
Water management	All workers trained
No water required for cultivation	Training of low skilled workers only
Rain-fed	Limited or no training
Efficient irrigation	**Local income generation**
Standard irrigation	Income for people that live in poor areas or belong to the poor strata of a country
Irrigation in water scarce region	**Local grower arrangements**
Water stress caused by project	Presence of acceptable arrangements for sourcing feedstock from local growers Independent producers and "outgrowers"
Water scarcity caused by project	**Community development**
Fertilizer management	Community development programme with full consultation
No fertilizer used	Community development programme with limited consultation
Controlled release fertilizers	Community development activities
Nitrification inhibitors	No community development
Liming	**Impacts on indigenous peoples**
Spot application/targeted application	Confirmed positive impacts on indigenous people
Use of cover crops	Negative impacts/simple mitigation
Avoidance of excessive wetness and compaction	Negative impacts/complex mitigation
Human rights	Unmitigated negative impacts
	n.a.

that may require further analysis and improvement. The categories represent a mix of qualitative and quantitative indicators, since many of the categories cannot be quantified over a range of feedstocks and projects.

The IDB uses the results of the Scorecard to evaluate project eligibility during the loan due diligence process. Scoring well on the Scorecard should not be considered an indication that the project will pass RSB's biofuels certification.[27]

World Bank

The objective of the **World Bank/WWF Biofuels Environmental Sustainability Scorecard** is to provide an indication of whether a proposed biofuel project is likely to have a (net) positive or negative impact on the environment. The Scorecard, which was modelled on the WWF World Bank Protected Areas Management Effectiveness Tracking Tool, aims to serve as a guide to facilitate consideration of key environmental (as well as social) issues in biofuel projects.

The Scorecard allows the user, through a descriptive scoring system, to:

- compare different biofuels and different biofuel production systems across key criteria in terms of environmental sustainability;
- understand what kinds of changes to production systems would result in more sustainable production; and
- track progress in improving sustain-ability over time.

The Scorecard is divided into four key components, under which the various environmental and social issues addressed in the Scorecard were included.

[27] See Inter-American Development Bank http://www.iadb.org/biofuelsscorecard/.

Following a broad overview of the major certification schemes for biomass and biofuels, we now turn to a more in-depth review of specific case studies. The selected cases address particular biomass-biofuel pairing within a specific country context and draw from in-depth studies to help gain a better understanding of implementation issues so that we can properly asssess these biofuel certification schemes.

3.3 Assessment of sustainability in biofuel feedstocks and implications for certification schemes

This section delves into specific studies to examine in more detail the implications of applying certification schemes, taking into account the specifics of the biomass-biofuel combination, the country or locality and the general features and requirements of the schemes. We begin with reviewing issues related to compliance with certification criteria, such as which criteria will be easier to meet, where bottlenecks might appear and the possible size of costs and benefits related to the adoption of sustainability criteria. Second, we look at issues concerning the conformity assessment, the direct costs and benefits of certification and how the product should be traced back to the producers. Given the little empirical research available on the subject, the cost and benefit assessments are mainly based on theoretical appraisals or studies of existing agricultural certification that are not necessarily in accordance with the schemes suggested for biofuel certification. Consequently, a certain extrapolation is required.

3.3.1 Soybean-biodiesel: Compliance cost with Basel Criteria in Brazil

In developing countries where soybean production is expanding, the key sustainability concern is whether the expansion occurs on grass- and forestlands with high carbon stocks. This is particularly an issue for Brazil where vast areas of grasslands for grazing are being converted to soybean plantations for biodiesel production, as well as to meet rising food/feed markets to compensate for US soybeans being increasingly used for biodiesel. Argentina also has great potential to become a soy biodiesel exporter. The following is a summary of two studies looking into soybean sustainability in Argentina and Brazil.

One of the certification schemes that could be important for soy in the future is the one suggested by the Roundtable on Responsible Soy Association (RTRS). The **Basel Criteria for Responsible Soy Production** were prepared in 2004 by ProForest in cooperation with WWF Switzerland, with the aim to "provide a working definition of acceptable soy production that can be used by individual retailers or producers".

As explained earlier in this chapter under Certification Schemes, there is also a standard for soy production (RTRS) which is an international multistakeholder initiative that was established in 2006 to promote sustainable soy production. A certification scheme for production and one for chain of custody have been implemented. Early in June 2011, the first farm was certified by RTRS and the certificate trading platform has already facilitated several transactions between certified producers and market stakeholders.

In 2004/05, an analysis on the compliance costs of meeting the Basel criteria was made for the case of Brazil. In special audits, ten representative farms in the regions of Paraná and Mato Grosso were evaluated. The study focused on the minimum requirements: no use of GMOs and the exclusive use of land that was not considered primary vegetation or high conservation value areas.

Results revealed that criteria linked to soil and water quality, as well as the use of pesticides, were met by all farms but one. However, they found that all the producers located in Paraná had converted primary vegetation and areas with high conservation value prior to 1994 (after 1994 no land conversion had taken place). The assessment and monitoring of environmental impacts was lacking in Paraná but the cooperatives to which the farmers belonged had agreements with different environmental organizations. The authors found that the cooperatives were good at providing information on environmental policies. Still, the possibility of small-scale members following the laws that regulate the extension of native vegetation was considered limited in the short term. In Mato Grosso, no land conversion had taken place. The farmers had fewer problems related to compliance with native vegetation standards, but generally lower knowledge of on-farm conservation and biodiversity. Social criteria were met by the farmers on nearly all points except for child labour. Fifty percent of the farms in both regions could not be considered GMO-free.

The authors concluded that the cost of certification would be rather low given that many of the criteria were already met. As the reviewed cooperatives already had experience in negotiating non-GMO premiums, their prospects for negotiating premiums covering the additional costs and a margin reflecting the cost of "good will" were rated as high. A soy crusher with production capacity of 20 000–250 000 metric tonnes was expected to demand a price premium of USD 9.50 per tonne, which would also include the audit cost of the crusher.[28] For retailers in Europe, a fully traceable soy meal meeting the Basel criteria would imply an extra cost of about USD 13.60 per tonne. The study acknowledged that opportunity costs of

28 About 5 percent of the producer price obtained in Brazil in 2005 (FAOSTAT, 2009).

avoiding land with high carbon stock might be higher in other regions, especially in the far north of Mato Grosso (Genetic ID, 2005).

Although the analysis gives an interesting first insight, the sample of ten farms is too low to provide any conclusions for Brazil as a whole. Further, it did not reveal more detailed characteristics of the farms (acreage, workers etc). As the case studies on Brazil and Argentina emphasized, one of the foremost threats to sustainability could be the conversion of forest- and grassland. Given the high economic returns of soy production, future research needs to include the high opportunity costs of preservation.

3.3.2 Cost estimation for sustainable ethanol in Brazil

A hypothetical assessment of the costs of sustainable ethanol in Brazil was conducted by Smeets et al. (2008). The study included 17 criteria, for which costs were calculated. As water pollution can become a problem where cane production is very concentrated, the cost of introducing water recycling and more efficient wastewater treatment raised total cost by 8 percent. While mechanical harvesting would solve the air pollution tied to cane burning, mechanization is too costly to implement and is not practical for all land. Further, mechanical harvesting does not require the same amount of labour. If the producers were to pay an unemployment compensation, this would increase costs by 8 percent.

The wages paid to workers in the sugar cane sector are generally above the minimum wage set by the government. Even so, a 50 percent increase in wages for unskilled labour resulted in overall rise of production costs by 4 percent according to Smeets et al. (2008) study. A difficult side effect to cost out was the health impact on workers related to manual harvesting (agrochemical poisoning, sugar cane soot, non-ergonomic cutting movements etc). Even though Brazilian legislation includes appropriate workers' rights, attention to reinforce them might be needed. The same was found for child labour, which was estimated to be 3 percent of the total workforce. In an attempt to calculate the foregone incomes for families where children work, as well as the expenses of sending them to school, the authors found that the ethanol costs would increase by another 4 percent.

In conclusion, the ethanol production costs were found to increase from 0.27 to 0.32 € per litre (18.5 percent) when adopting best management practices (no cane burning, reduced tillage and compliance with relevant Brazilian legislation). Using organic sugar cane would reduce the additional expenses by 1 cent per litre as yields were estimated to be higher (0.31 €/litre or a cost increase of 14.8 percent). When taking the social criteria into account, costs would increase by 37 percent, to 0.37€/litre. The direct cost of certification was estimated to be 0.5 percent of the total cost. Other criteria, such as biodiversity and food security, were difficult to quantify as indicators are lacking. Regarding food security, increased sugar cane production could lead to higher land prices and have adverse impacts on food production. These impacts would have to be compared with the possible positive impacts on farmers' incomes. Overall, according to this study, although costs for sustainable cane ethanol are higher than the costs of conventional cane ethanol, the increase would not be unbearable.

3.3.3 Argentina: Organic sugar and sustainability benefits

A study considering mostly small sugar cane growers in the northeast of Argentina (San Javier region) was conducted by Serrano in 2003. Six hundred farmers were included, with an acreage of about 1 500 ha of land. Organic farming methods were introduced after the local mill was taken over by the provincial government in an attempt to make production profitable. Most of the plots were between 10 and 25 ha (61 percent). There were substantial differences in efficiency due to economies of scale. Moreover, the largest farms usually had other cash crops (tobacco and citrus), cattle and forest, while small-scale farmers tended to have sugar cane as their only cash crop.

In view of the costs, organic farming was found to be 10 percent more costly than conventional farming. Conventional farming had higher expenses for herbicides and fertilizers as well as for transportation (because of the higher yields). By contrast, costs for harvesting were higher in the organic system. The largest difficulty was the drop in yields (from 60 to 45 tonnes per ha) (Table 3.4).

On the other hand, the net profit for 1 ha (USD 367) of organic sugar exceeded the net profit of conventional sugar by more than double (USD 168). Further, the author found positive impacts on the environment and health of the farmers who were now less exposed to toxic agro-chemicals. Perhaps the most important benefit, however, was reported to be the easier market access and the possibility to continue sugar production in the region. While completing the analysis, representatives of the provincial government were also promoting the inclusion of other cash crops in the organic supply, arguing that audit fees would increase only disproportionately.

A social advantage of organic farming was related to the use of manual labour instead of pesticides and herbicides. As a result, new jobs were created where other possibilities to obtain paid positions were limited.

TABLE 3.4 - COSTS AND BENEFITS OF CONVENTIONAL VERSUS ORGANIC SUGAR IN SAN JAVIER, ARGENTINA

Activity	Explanation	Cost in USD (per ha in 2001)	
		Conventional	*Organic*
Planting	No difference	498	498
Fertilizers	Slight cost increase with first time organic fertilizer	53	(54)
Soil conservation measures	Soil rotation necessary. Too early for cost evaluation	-	NA
Weeding	With burning practices phaseout, less weed growth; manual weed control was more labour-demanding in first year	42	56
Harvesting	More careful cutting in the organic system, as the leaves need to be cut to cover the soil	84	126
Transportation	Lower costs due to the lower yields	300	225
Post-harvesting	Possibly higher costs for organic farming to reduce amount of fungus	-	NA
Certification fee	Very high for small-scale farmers; subsidized by the provincial government	-	51-56
Total cost		562	568
Price (sugar cane)		12	21
Price (sugar, FOB)		320	500
Yield		60	45
Net profit (including certification cost)		168	367

Source: Serrano, 2003

In spite of these benefits, the mill was still not profitable at the moment of the assessment. One of the reasons was said to be the low workload (50 000 tonnes compared with 100 000 tonnes capacity). To make production viable, the producers would have had to increase the crop area to allow for a capacity of 60 000 tonnes. The author concluded that the provincial government had been crucial for implementing the organic programme. Subsidized audit fees and research on new technologies and varieties throughout the process made it possible for the farmers to convert production without running too high a risk.

The study by Planeta Organico (2004) did not include considerations on life-cycle emissions from sugar cane and the ethanol production process. However, as has been demonstrated by various authors, organically produced sugar and ethanol generally emit fewer greenhouse and ozone-depleting gases and have a better energy balance (e.g. Seabra and Macedo, 2007, Monteiro et al., 2008, see also Pelletier et al. 2008). The Brazilian case shows that organic sugar cane does not necessarily need to have lower yields but can produce even higher yields than for conventional sugar. Yet, as commented above, the Brazilian sugar industry is highly concentrated. If a more widespread ethanol certification becomes established the question may arise whether significantly high price premiums will continue to prevail and whether the small-scale farming structure can compete with the large plantations. In fact, the Argentinian mill encouraged farmers to increase their land to at least 1.5-2 ha (17 percent had only 1 ha) as the certification cost was hard to recompense for smaller farms.

3.3.4 Democratic Republic of the Congo: short-rotation trees (Eucalyptus)

Eucalyptus has been grown on the sandy savannah soils in the district of Pointe Noire in the Democratic Republic of the Congo (DRC) for over 25 years. Traditionally, the feedstock has been aimed mainly at the paper and pulp industry. However, pellets for modern bioenergy appliances have the potential to become an alternative outlet. For example, Canadian MagIndustries finished a chip mill with capacity of up to 650 000 tonnes of wood chips per year in 2008. The bulk of the chips will be exported to Europe (MagIndustries, 2009).

In the DRC, the soil used for eucalyptus usually has a high sand and acidity level and therefore is lacking in nutrients. Hence, a number of studies have shown that conversion of the low-yielding savannah may have positive impacts on natural vegetation and biodiversity (see e.g. Martin, 2003). On the other hand, nutrient losses take place through logging and preparing the land by burning. Accordingly, field experiments typically show a decline in soil carbon in the beginning, followed by an improvement when the trees start to grow and the organic matter increases. How long it takes and whether it is possible to reach an equivalent or higher level of soil carbon than before is correlated with the soil quality prior to the conversion. For example, Hartemink (2003) observed that soil organic C was higher in eucalyptus plantations than natural savannah (6.5 g C/kg compared with 8.8 g C/kg) with a similar level of nitrogen. However, if production takes place on high-yielding grassland, a decrease is possible (for a longer review, see Nouvellon et al., 2008). Efficient nutrient management includes the adoption of varieties that have favourable litter features and decomposition rates (Bernhard-Reversat, 2001).

In the DRC, the eucalyptus plantations are based on tenant farming schemes (Amsallem et al., 2003). A law aimed towards sustainable forest management practices was passed in 2000. The law prescribes the preparation and implementation of management plans for all forest management units. According to *Illegal Logging*, an internet platform focusing on illegal deforestation, the government has been successful in engaging local stakeholders and NGOs (Illegal Logging, 2009).

One issue concerning agriculture and forestry is the contested use of genetically modified crops. In the DRC, the plantations are based on very productive clones. Proponents argue that it has been a way to increase yields and reduce the problem of insects and disease as well as the content of lignin – a residue that is costly to remove. (Cossalter and Pye-Smith, 2003).

Estimations show that the eucalyptus plantations generated 1 400 direct jobs between 1978 and 2003, which is about three jobs per 100 ha (Cossalter and Pye-Smith, ibid). However, an NGO commented that in 2001 the largest plantation required only one job for 105 ha (WRM, 2001). Nevertheless, the impacts on rural development and social welfare are not restricted to direct jobs. For example, as observed by Evans and Turnbull (2004), positive effects can also be achieved as a result of the increased wood and charcoal supply.

In sum, this example shows the potential multiple benefits of planting biomass in terms of improved soil quality and higher productivity as well as higher income and social (labour) benefits. The example also demonstrates the benefits of enforced sustainability regulations to mitigate against negative unintended effects such as deforestation. Still, much can be done to ensure that existing tenant farming schemes are protective of small-scale farmers' rights, especially under the prospects of large-scale investments and production expansion.

3.3.5 India: Jatropha-biodiesel and sustainability

India's national biofuel strategy rests on developing biodiesel production capacity from non-edible oil seeds using waste-based feedstocks or cultivation of crops in degraded or marginal lands. India's Government has approved an indicative target of 20 percent blending of biofuels, both for biodiesel and bio-ethanol, to be reached by 2017. India also provides price support in the form of a minimum support price (MSP) for non-edible oil seeds with periodic revisions to provide fair prices to the growers and a minimum purchase price (MPP) to purchase bio-ethanol and biodiesel. Investments in research and development will focus on plantations, processing and production of biofuels, including second-generation biofuels. Likewise, financial incentives, including subsidies and grants, are also considered for second-generation biofuels. A National Biofuel Coordination Committee, headed by the Prime Minister, is set up to provide policy guidance and coordination, while a Biofuel Steering Committee, chaired by a Cabinet Secretary, will oversee implementation of the policy (Ray and Bhardwaj, 2008).

Since the objective is mainly to meet the growing domestic demand, certification schemes for exports may appear less critical (see e.g. Morel, 2007). However, because of insufficient domestic distribution facilities, India began exporting biodiesel to the EU and the USA in 2007, thus requiring India to face up to certification requirements, especially from the EU (Cleantech Group LLC, 2008). Moreover, a domestic certification scheme has been under discussion and the national certification body, The Quality Council of India, has shown interest in developing standards for third-party certification (Chaturvedi, 2009).

One of the major bottlenecks for biofuels based on Jatropha is the economic viability. Until now Jatropha has only been cultivated on a small scale and breeding activities to increase the seed and oil yields have been very limited. In poor conditions, seed yields might not be higher than 1 kg per tree. Irrigation, fertilizers, pesticides and fertile soil generally bring about a substantially higher amount of seed (up to 3.5 kg per tree). However, the cultivation under these conditions makes opportunity costs higher and most farmers still prefer to grow Jatropha as a living fence or as a complement to other more profitable crops (Altenburg et al., 2009).

One way to decrease opportunity costs has been to promote the use of wastelands. About 17.5 percent of the total Indian land area is classified as wasteland, such as deteriorated scrubland, degraded forestland and barren rocky land (Ministry of Rural Development, 2005). According to the government of India, 13.66 million ha of this could be cultivable (Government of India, 2007). As a perennial tree, Jatropha could help to restore the soil quality of the land. Jatropha also fits nicely with India's policy to avoid using food/feed crops for biofuels (Jongschaap, 2007). In 2008, about 60 percent was grown partially or totally on wastelands (GEXSI, 2008).

Jatropha could offer many attributes in favour of sustainable biofuels. Reinhardt et al. (2007) showed that Jatropha biodiesel produced in India could reduce GHG emissions by between 0.13 and 1.05 t CO_{2eq} (about 10-75 percent less than conventional diesel) per year per ha for land with no or scarce vegetation and a timeframe of 20 years. Even better results could be achieved if the yields are further increased and when the by-products are used for energy generation instead of fertilizers and feed.

Yet water pollution from runoff water is a concern. A study by GEXSI (2008) found that negative effects of pesticides and fertilizers were limited when production was rain-fed and degraded land was used (the majority of the plantations). Five case studies conducted in Andhra Pradesh, Maharashtra and Uttaranchal showed that farmers already met criteria related to good agricultural practices and the efficient use of inputs (in particular water use). By contrast, criteria related to biodiversity and above-ground carbon conservation were not considered (Morel, 2007). Also pests could become a problem. As Jatropha cultivation spreads to other regions, it might be more susceptible to disease.

Jatropha cultivation could further have a positive impact on rural growth and employment. Ninety-two percent of the Jatropha producers used out-grower schemes (GEXSI 2008). The harvest does not take place within the rain season in June/July, when most farmers are involved in other agricultural activities (Altenburg et al., 2009).

Among the disadvantages of Jatropha is the little experience farmers have with the commercial cultivation of this new crop. In addition, the growth period of three years is comparatively long. Moreover, Jatropha is harmful to health and the people who are in contact with the feedstock or the by-products need to receive adequate training. Moreover, the promotion of Jatropha in India has yet to tackle the thorny question of land rights and how to compensate for rural communities who currently use wastelands for many purposes (firewood, food, fodder) (Rajagopal, 2007).

3.3.6 Ghana: Jatropha-Biosdiesel prospects and sustainability

Ghana is one of the African countries that has been active in promoting biofuels. It has set up a national biofuel policy that recommends the substitution of 20 percent of natural gas and fossil oil and 30 percent of kerosene by Jatropha by 2015 (Jumbe et al., 2007).

One key advantage of promoting Jatropha is the potential of the crop to restore the ecosystem and improve soil quality and to decrease soil erosion. There are also indirect effects. Ghana has an estimated 16 000 km^2 rain forest. An assessment based on satellite images showed that deforestation has been intensified with an annual depletion rate of nearly 2 percent in the last years. The main reason for this has been related to mining and lumbering but also because of fuel wood removal (Kusimi, 2008). Jatropha oil for electricity and cooking in households could be a way to limit deforestation.

Further, rural development and food security are two important issues. Ghana has been able to reduce the number of undernourished people by 65 percent between 1990 and 2003/05. However, the minimum dietary energy requirements are still not met for 9 percent of the population (FAO, 2009a). Jatropha cultivation has the potential to increase jobs and rural incomes. Further, Jatropha can be intercropped with food staple crops and the government has earmarked idle and degraded land (Amoah, 2006). Hence, the risk that it will compete with food for land and productive resources is not as large as for other energy crops that require more input. In addition, it is not edible (unlike, for example, feedstocks like cassava that have been estimated as risky, Caminiti et al., 2007).

There is a growing debate in Ghana about the merit of Jatropha and farmers are divided over its benefits and costs. As in the case of India, the main constraint of Jatropha biodiesel production in Ghana is the economic and financial viability. Farmers have a mixed reaction to Jatropha, mirroring recent reports suggesting Jatropha is not as hardy, climate-friendly and food security-neutral a crop as once hoped. On the plus side, the Jatropha plant can withstand tough, arid conditions not tolerated by food crops, so it can be grown on land unsuitable for food production. But Jatropha is temperature-sensitive, requires fertilizer to thrive and generates a relatively low yield when grown on marginal lands. These concerns have dented the former excitement about this crop, and permitted rising complaints against this plant. Foreign investments in land for Jatropha production have receded recently because of an anti-Jatropha campaign by the civil society organizations in Ghana. There is concern that growth of Jatropha may come at the expense of Ghana biodiversity and that large land acquisitions for Jatropha may clash with food security needs, according to the Ghana's Food Security Policy Advocacy Network (FoodSPAN). Given the lack of financial viability of Jatropha at prevailing market conditions, private investment in Jatropha plantations for biodiesel has waned (GRAIN, 2011).

3.3.7 Palm oil-biodiesel: Malaysia

In view of its high oil content, oil palm is a more efficient biodiesel feedstock than many other oil crops in terms of land use. As much as ten times the amount of biodiesel can be produced from one ha of oil palm as from soybean (Lam et al., 2009) while energy balance from palm oil biodiesel is comparable to that of sugar cane ethanol (Reinhardt et al., 2007). Further, palm oil biodiesel could generate GHG emissions savings of up to 38 percent if land-use change is not factored in (Yee, 2009).

However, growing oil palm for biodiesel has been contested, especially when tropical forest and peat forest are at stake. Growing oil palm in tropical rain forest and peat forest could have a high negative carbon cost; estimates of the payback time for the carbon debt could be 86 years for tropical forests and 423 years for peat forests (Fargione et al., 2008). Moreover, pollution is aggravated from burning practices during deforestation to grow oil palm in Southeast Asia.

Processsing of residues (fibres and kernel shells) to produce heat and power in the mill is another source of air pollution as residue combustion induces air emissions (nitric oxides, hydrocarbons and particles). Generally, exhaust gas systems in the mills are insufficient to cope, especially in cases where the empty fruit bunches (EFB) are burned to avoid disposal costs (Reinhardt et al., 2007). For mills without modern plant treatment facilities, palm oil mill effluents (POME) can cause serious risks for the water quality (Sheil et al., 2009).

In Southeast Asia and many parts of sub-Saharan Africa, palm oil is the cheapest source of vegetable oil but rising use for biodiesel raises concern over food security as palm oil prices increase, especially for urban consumers. However, for many farmers, higher prices offer added incentives to invest more in oil palm production. In Indonesia and Malaysia, smallholders are responsible for 33 percent of the oil palm produced, and in Nigeria and Ghana, the share is 80 percent. Their income often fluctuates with the market prices, but revenues from palm oil typically exceed the alternatives in major oil palm-growing areas, especially in Africa. Hence, biofuel production could help by increasing the market opportunities and reducing price uncertainty (Vermeulen and Goad, 2006).

Malaysia is one of the world's leading palm oil producers and exporters. The oil palm sector employs many workers and is one of the largest income sources in the country. The government has actively promoted the cultivation as part of a strategy to reduce rural poverty; one-third of oil palm farmers are still smallholders. The Federal Land Development Authority (FELDA) distributed about 800 000 ha in cultivation to about 100 000 families (Vermeulen and Goad, 2006). Johnston and Holloway (2007) estimated that the conversion of palm oil to biodiesel at its full potential could reduce unemployment by 2 percent and increase the GDP per capita by 2.3 percent.

Malaysia is very sensitive to sustainability demands, especially from the large European market. Many biofuel sustainability schemes specifically target palm oil producers like Indonesia and Malaysia. This came on the heels of studies reportedly pointing to negative links between oil palm and sustainability. Since 2008, several studies linking oil palm to deleterious environmental impacts were reported and highly publicized. For example, Koh and Wilcove (2008) found that 55-59 percent (1 040 000-1 109 000 ha) of the palm oil expansion between 1990 and 2005 took place on forest land. These authors focused particularly on forest butterflies, whose population was estimated to have contracted by up to 83 percent.

The Malaysian Government launched a number of sustainability measures. For example, the country imposed a zero-burning policy in the 1990s and measures have been taken to face the problem of effluents (Sheil et al., 2009). To tackle high air pollution emissions, direct burning of the EFB was prohibited. Malaysia also moved to regulate agrochemical use, outlawed the use of the harmful herbicide paraquat and encouraged an alternative herbicide, glyphosate, as well as biological methods (Sheil et al., 2009).

A case study (Norwana et al., 2011) in Sabah state of Malaysia assesses the social, economic and environmental impacts arising from oil palm cultivation in order to draw lessons for an incipient biofuel sector. Key-informant interviews, household surveys and focus-group discussions with various local stakeholders point to largely positive impacts from oil palm on local livelihoods, particularly independent oil palm growers and migrant employees. Communities with no firm titles to the land showed little resistance when they were not consulted over the allocation by the state to plantation companies. The study showed a negative impact of palm oil cultivation on the environment, while there is a strong positive social impact in terms of alleviating poverty and providing a better standard of living to many rural communities. There are few economic alternatives that compare with oil palm in terms of net returns in the region.

A study on organic certified oil palm in Malaysia by Nordin et al. (2004) could provide an idea of what to expect in terms of costs in the case of palm oil biodiesel. The study was based on a plantation of 5 000 ha with a dedicated processing mill. In a first step, the authors looked at different input factors where organic farming generally implies additional costs/benefits. Fertilizers are a crucial factor for oil palm farming. Because organic farming excludes chemical fertilizers, different organic methods are required. However, they are generally less efficient than the chemical equivalent. Therefore, larger amounts are needed and this could increase costs (about three to four times as much when considering the recommended 6 tonnes per year per ha). A way to reduce these expenses is to use EFB and POME. The use of fronds to cover the earth is another cost-efficient possibility to help conserve the soil. Further, the habit of cultivating legumes in the immature phase can be a way to reduce the need for nitrogen fertilizers. Finally, no-burning practices generally improve the soil quality. Taking these factors into account, the authors found that organic fertilizers would be about three times as expensive as chemical fertilizers.

For weed control, use of cover crops and EFB cover as well as mechanical weeding were assumed, with costs about four and one-half times as high as for conventional weed control. Organic pest controls include biological pest control with insects and plants, bio-pesticides, pheromone trapping to reduce the prevalence of rhinoceros beetles, as well as mechanical practices, but overall cost share is still small (1 percent of total) and the same as for conventional farming. As the pest control only has a small share in total costs of oil palm cultivation (less than 1 percent), the same costs as for conventional farming were considered.

The authors further assumed that organic cultivation will require higher amounts of labour and consequently higher labour costs (10-20 percent). They did not expect any change in yields or in the costs for the processing. However, costs for transportation were assumed to increase because of the need to move EFB and POME from the mill to the field. Total costs are presented in Table 3.5.

Annual certification costs ranged between RM 20 000 and RM 35 000 (about USD 5 200-9 100 for 2004). In total, organic palm oil production costs were estimated to be about 33 percent higher than conventional palm oil (for 1 tonne of oil RM 935/t compared with RM 626.35/t).

In a second step, the authors tried to estimate when oil palm farmers would choose organic production over conventional farming. They found that when the price for conventional production was RM 1 000 (USD 203)[29] per tonne of palm oil, the price for organic palm oil would have to be RM 1 535 (USD 312) to generate the same profits. However, the authors stressed that although other organic vegetable oils have had price premiums close to this point, they tend to decline with time. Therefore, they argued, the price premium should not be the only determinant in adjusting to organic methods but also such factors as the possibility to enter new markets, as well as environmental and social benefits (such as a better image of Malaysian palm oil and more work opportunities).

Exploring to what extent the criteria of organic farming can be compared with future biofuel certification schemes, Fehrenbach (2009) looked at the costs of palm oil according to the RSPO standard (which he assumed to be extensively sufficient to cover many of the issues mentioned in many of the certification schemes except for some aspects, such as GHG emissions). He came to the conclusion that compliance with the RSPO criteria (such

[29] Exchange rate of 19 June 2009.

TABLE 3.5 - ESTABLISHMENT AND UPKEEP COSTS OF CONVENTIONAL VERSUS ORGANIC CULTIVATION, FIRST YEAR (RM/HA)

Item	Conventional	Organic
Non-recurrent		
Felling and clearing	724	724
Terracing and soil conversation	215	215
Roads, bridges, paths	175	175
Drains	134	134
Survey, lining, holing and planting	189	189
Planting material	666	666
Subtotal	2 103	2 103
Maintenance		
Road, bridges, paths, etc.	70	70
Drains	50	50
Terraces	50	50
Soil/water conservation	40	40
Boundaries and survey	30	30
Subtotal	240	240
Upkeep		
Weeding and lalang control	219	984
Cover crops and beneficial plants	169	338
Pests and diseases	54	54
Pruning	20	20
Census and supply	24	24
Other costs of upkeep	54	54
Subtotal	540	1 474
Fertilizers	227	681
Total	**3 110**	**4 498**
Total (excluding non-recurrent costs)	**1 007**	**2 395**

Source: Nordin et al., 2004

as compliance with legal requirements, more environmental-friendly cultivation, "fair" wages, etc.) would probably lead to higher expenses, but still comparably small – in the range of € 2 per tonne. By contrast, compliance with the GHG criterion of the Renewable Energy Directive (RED) (<35 percent), could be linked with higher costs, as it would be necessary to diminish wastewater pollution from the biodiesel production process. The wastewater treatment often takes place in open anaerobic lagoons, which results in large methane releases. To avoid this, the wastewater can be recycled in biogas plants. The investment cost for such a plant was estimated to be € 5 million for a capacity of 10 tonnes of oil per hour and 30 000 tonnes per year. With a recovery period of 20 years, this would imply additional costs of around € 8.30 per tonne (although reduced electricity costs and potential benefits of selling purchase electricity could have a favourable effect). When accounting for this and the direct costs of certification, total costs could amount to between € 14 and 17 per tonne (an increase of between 3.5 to 4.5 percent of total costs in the end of 2008).

However, these estimates need to be viewed with caution. The cost estimations of Fehrenbach (2009) were based on palm oil producers that have been or are in the process of certification, and hence have already complied with the criteria. So the costs could be higher for most farmers on average. Even so, the cost estimation of Nordin et al. (2004) was clearly much higher than the estimation of Fehrenbach (2009). Other issues not considered in these analyses include the land dynamics and land-use change. As land is a scarce resource in Malaysia, the opportunity costs of not using peatland could be high.[30] More work is clearly needed in this area.

3.3.8 Cassava-ethanol: Thailand

Cassava offers many properties that make it highly suitable as biofuel feedstock. It grows well under soil and rainfall conditions that are sub-optimal for other crops. Also cassava is a well established crop in many regions of the world making it a readily available feedstock. In Africa, south of the Sudano-Sahel zones, cassava is an important subsistence food crop. Hence, increased cassava biofuel production could come into conflict with food security. At the same time, it is possible that renewed research and development programmes for cassava could lead to a win-win situation, whereby improved yields and post-harvest processing technologies could not only expand productivity at the farm level, but improve marketability of the surplus, providing new income sources for farmers and serving to meet added demand for biofuel production.

Thailand is the country where cassava production for biofuels is most advanced. Thailand is one of the world's largest cassava growers and has traditionally produced mainly for export. As was pointed out by Nguyen et al. (2007), there are a number of factors that favour cassava production for bioenergy in Thailand; given the long tradition in cultivation, research institutions have already made many efforts to improve the varieties and adapt them to the Thai farmers' conditions. As a result, yields have increased by more than 50 percent between 1995 and 2004, to 20 tonnes per ha. Cassava also has an advantage over sugar cane – the second large biofuel feedstock in the country – in that the production process is not dependent on the season as it can be cultivated and harvested any time of the year. The possibility to produce ethanol out of dried chips makes it more flexible than sugar cane. In addition, cassava is mainly produced in small farming systems with little input. As prices have been fluctuating during recent years and supply was generally higher than demand, ethanol production was seen as an added driver of demand and further support for rural growth. In view of the GHG reduction potential (the authors estimated it to be 62.9 percent when no land use conversion occurs), Thai cassava ethanol meets the criterion set in the EU and various certification initiatives. The authors also made an estimation of GHG abatement costs, which were calculated to be USD 99 per tonne of CO_2 equivalent. Compared with other GHG reduction strategies, this was a rather expensive alternative. However, as the Thai industry develops, long-run average industry costs of abatements could come down.

Deforestation and the spread of monocropped cassava for biofuel could exact a heavy cost on biodiversity. The heavy deforestation connected with the cassava expansion in the Northeast of the country in the past has likely contributed to a loss in biodiversity (compare FAO, 2001). This is a major potential concern to explore.

Depending on where it is grown, cassava cultivation may present a serious soil erosion problem since the plant has a low soil cover. The problem is made worse by the deep tillage required for collecting the roots and the fact that cassava is often

[30] For example, Agus et al. (2007), estimated the opportunity costs (here defined as "the cost for avoided deforestation" (...) "based on the net profit per unit area per unit time divided by net carbon emission per unit area per unit time" s. 3) of avoided deforestation in peat districts of Indonesia to between USD 9 and 361 per ha per year.

grown on already degraded land with high slopes (Valentin et al., 2008). Methods to help limit soil losses and restore nutrients are: fertilizers, intercropping with peanut, no tillage, contour farming and hedges (grasses, pineapple and legumes). A study coordinated by the International Center for Tropical Agriculture (CIAT) showed that 23.5 percent of the Thai cassava growers use hedgerows and 30.3 percent use contour ridging. Over 90 percent use chemical or organic fertilizers (Howeler et al., 2005).

Thailand has ratified five of the basic ILO Conventions (including the ones referring to child labour, forced labour and equal wages for men and women). Despite improvements in the last 30 years, the labour situation still shows problems, particularly with child labour and minimum wages, and the agricultural sector is one of those with the least protection. Regulations concerning minimum wages do not apply for the agricultural sector and according to ILO (2008) approximately 37 percent of the people working in the cassava sector earned less than the minimum wage in 2007.

Thailand has been successful in reducing food insecurity in the last decade, but in 2003 between 15 and 25 percent of the people in the country were still undernourished (FAO, 2009a). Only a very small amount of the cassava production goes into food processing, hence no direct impacts on the local food availability are expected. However, a study by Amatyakul and Berndes (2007) came to the conclusion that the expansion of cassava in the Northeastern region in 1986-2005 has mainly occurred at the cost of maize and to a lesser extent on pastureland and non-crop agricultural areas. For most of the Eastern region, cassava has replaced rice but also some pastureland. In other words, an indirect impact of the cassava production could be higher prices for crops such as maize and rice. These impacts would have to be balanced against the higher income from cassava production and avoided fuel imports.

According to Schmidhuber (2007), cassava ethanol is viable at gasoline prices between approximately USD 0.28 and 0.33 per litre, which is better than the ethanol produced in the United States and Europe. Variable costs account for about 80 percent of total costs with labour costs at the top followed by land rent and materials. During the field operations, weed control is the most expensive factor (Sriroth et al., 2006). One possibility to reduce labour costs is to use animals or mechanize the inter-row planting, as well as to introduce herbicides. In view of the low unemployment rate (2 percent in 2007[31]), this can also be a means to avoid labour shortages (Ratanawaraha et al., 2001).

In a survey of 17 cassava-producing households in Nong Mai Daeng, Thailand, Facius and Ipsen (2006) found that fertilizers were ranked as the highest bulk of expenditures before labour and seeds. Organic fertilizers (usually cattle or chicken manure) were about 50 percent more expensive than the chemical fertilizers used for cassava production. In contrast, the return of investment was substantially higher for organic fertilizers (12 THB compared with 22 THB, i.e. for every THB invested in organic fertilizers a return of 22 THB was achieved). Accordingly, many of the surveyed cassava farmers already used organic fertilizers. The study included only a very small sample, but organic farming is relatively new in Thailand.

3.4 Conformity assessment issues

A certification scheme often implies an issuance of a label or symbol that signals that some standard(s) have been met. Unlike the certificate, which provides information for distributors and vendors, the label serves as a signal for the end consumer. In most

[31] ILO, 2008.

cases, labelling is a private initiative that the producers apply for voluntarily (Grote, 2009)

Apart from the costs and benefits related to the compliance with sustainability criteria, the certification scheme incurs direct costs (such as audit fees). At the same time certified biofuels may or may not generate price premiums depending on a host of factors including market power, the existence of readily substitutes, etc. Audit fees for some certification organization are listed in Table 3.6.

It is important to note that the costs can vary substantially depending on the location of the business, the time needed to accomplish the audit, the certification body, etc. Vis et al. (2008) compared different studies for estimating the direct costs of an FSC certification. Only studies on European countries were included, and the authors postulated that a similar certification in developing countries would probably be more expensive. For the external auditing, they found that the costs amounted to about €10 000 for an area between 8 000-16 000 ha in the beginning of 2 000. Annual follow-up audits came to about €5 000. They also looked at the costs linked with the preparation of the external audit. In the case of Germany, they found that it would cost the company about €5 000-15 000 to hire a consultant depending on the working hours required (between 88 and 228). If the company did it independently, costs were usually lower.

When comparing different scales, they observed that the direct costs for a forester with only 100 ha would be far more than a large-scale producer with 60 000 hectares (15 and 0.07 €/GJ respectively). Clearly, the organization of smallholders would be a more economical alternative. The authors suggested that the introduction of a common resource manager for the special purpose of certification, or the use of prevalent cooperatives or associations could be a way to reduce costs. By contrast, the costs of organizing cooperatives just for building up a certification system might be too high.

Nussbaum et al. (2001) came to similar conclusions when looking at the constraints experienced by small forest owners. They found that the minimal cost for an FSC certification procedure is USD 1 000 – an amount that can be very high for smallholders in developing countries.

Price premiums often depend on negotiations between retailers and producers. In some cases, they can be very large (e.g. in the case of organic bananas, where the markup can be 50-200 percent, Scialabba, 2000), while in other cases they are marginal (often the case for forest products, Durst et al., 2006). The extent to which a higher price can be received generally depends on the end use of the product as well as the quantity sold (Vis et al., 2008). Price premiums are not necessarily the most important reason why producers show interest in certification. A study evaluating the main drivers for forest certification in the countries of the United Nations Economic Commission for Europe (UNDESE: mainly countries belonging to Europe as well as Canada, Israel, Turkey, the United States, and countries in Central Asia) found that market access and environmental image rank before expected premiums by forest owners (Raunetsalo, 2002).

As the attempts to certify the whole biofuel production chain is still in the initial stage, audit costs and possible price premiums are difficult to assess. A study by Purchas and Hutchinson (2008) looked at the case of New Zealand. The analysis was based primarily on tallow biodiesel produced domestically and sugar cane ethanol imported from Brazil. They found that the assessment of the fuel against social and environmental criteria (including GHG emissions) could be between NZD 12 000-15 000 per producer and year (about USD 7 000-8 750). An independent

TABLE 3.6 - DIRECT COSTS AND BENEFITS OF OPERATIVE SCHEMES

Organization/ Company	FSC	IFOAM	SAN	RSPO	GLOBAGAP (FORMER EUREPGAP)
Audit Costs	USD 1 000-20 000 annually (6-26 cents per acre in the US)[a]	USD 220-2 750 annually for companies between USD 115 160 and 3 450 000 turn-over per year. For companies over USD 3 450 000 annual turnover, USD 3 850 annually[a]	Audit fee depending on local audit body	Euro 10 000-25 000 for the first audit, after that about 80% of the first audit annually.[b]	Cost of assessment charged by certification body[a]
Direct benefits	Price premiums are subject to negotiations between seller and purchaser, easier market access[b]	Price premiums are subject to negotiations between seller and purchaser, in Australia premiums in the range of 80% have been reported, easier access to niche markets [b]	Price premiums are negotiated between seller and purchaser, SAN provides assistance in finding markets		No price premium, better access to supermarket chains[b]
Group certificates	Yes[a]	Yes[a]	Yes[a]	Under development[a]	Yes[a]
Small-scale	Special programme for small and low intensity forestry[c]	The limited input use and care for natural resources could favour small-scale farmers[a]	Annual certification fee according to farm size[a]	Has a working group on smallholders but the main focus is on large-scale plantations. The oil palm plantations that have already been certified were between 1 300 and 9 300 hectares large[b]	Expensive[a]
Source:	[a]Purchas and Hutchinson (2008) [b]FSC (2009a) [c]FSC (2009b)	[a]Purchas and Hutchinson (2008) [b]Willer et al., 2008	[a]Rainforest Alliance, 2009 [b]FairMatch Support (2009)	[a]Purchas and Hutchinson (2008) Fehrenbach (2009)	[a]Purchas and Hutchinson (2008) [b]FairMatch Support (2009)

audit would cost the producer another NZD 5 000-10 000 per year (USD 2 900-5 800). The authors did not include any price premium in the calculations, as they assumed that the large share of the biofuels used in New Zealand today would already meet the sustainability criteria. When considering other biofuel sources (such as palm oil biodiesel), a price premium of about USD 0.06 was included. This would imply a price increase of biofuels at the fuel station of 1-3 percent.

Tracking principles

When introducing a standard or certification programme, a relevant issue is how to follow the product path in the value chain. The tracking system is a way to communicate the qualities of the product (where it comes from, under which conditions it was grown, etc.) and/or provide assurance that the amount of sustainable bioenergy bought by the customer was actually added to the market. However, the tracking system might also be connected to rather high expenses. The amount of information required to make the system reliable without inducing too high a cost is a critical question for policy makers (Turner et al., 2007).

A concept that has recently emerged from the biofuels supply chain analysis is the chain of custody. It relates mainly to certification schemes and it basically refers to the chronological documentation, or paper trail, showing the seizure, custody, control, transfer, analysis and disposition of evidence, physical or electronic, of a particular product. Establishing the chain of custody is both a chronological and logical procedure, especially important when the chain consists of fungible goods that need to be traced.

There are basically three different systems that come under consideration: "physical segregation", "mass-balance" and "book-and-claim". As the name suggests, physical segregation refers to the actual segregation of certified products from non-certified products. The principle can further be divided into a track-and-trace system (where it is possible to trace back the product to a region or country, for example) or bulk-commodity goods (which are strictly separated from non-certified goods but where the traceability is not guaranteed). The advantage of physical segregation is its transparency and reliability. However, the system also implies rather high costs as the infrastructures for certified and non-certified produce cannot be shared. Depending on the commodity and the level of credibility being sought, different systems are chosen (for example, forest certification systems often use a track-and-trace arrangement while organic farming is generally based on a bulk system).

By contrast, the "book-and-claim" principle does not distinguish between certified and non-certified products, but disconnects the certificates from the products. For instance, in the case of biofuels, farmers could have the possibility of obtaining certificates from an issuing body, which ensure the compliance of production with a sustainability standard. Fuel providers then have the opportunity to buy these certificates. When the fuel providers sell fuels and declare that they were derived from biomass produced in a sustainable way, they need to return the certificates to the issuing body in order to avoid a double-count. This kind of system is generally cheaper and faster to implement than the former, as the suppliers do not need to make any investments in new logistics.

At present the RSPO does have a book-and-claim system, run through GreenPalm (http://www.greenpalm.org/). RSPO-certified palm oil producers are invited to register a quantity of their output with the GreenPalm programme. They are awarded one GreenPalm certificate for each tonne of palm oil which has been sustainably produced. They can then put those certificates up for sale on the GreenPalm web-based trading platform. Manufacturers or retailers can then bid for and buy those certificates online, in order to be able to claim that they have supported the sustainable production of palm oil. Consumers can then make environmentally responsible purchasing decisions. The palm oil itself is sold, processed and purchased in the usual way.

Thus far, compliance costs and direct certification costs for palm oil biodiesel from RSPO are reported in Table 3.7 under three supply chain scenarios.

For the producer in the beginning of the value chain, the price premium of sustainable production might be higher because he sells the certificate directly to the retail dealer and is not as exposed to the market power of the actors further down in the value chain. On the other side, the separation of production and certificates also means less transparency. There is no way for the end consumer to be certain the product he bought was really produced according to sustainable management methods, only that an equivalent quantity has been brought to the market. For liquid biofuels that are physically equal to fossil fuels, this might not be a problem. But where a certain quality of consumption is desired (e.g. that the product does not contain pesticides), the physical segregation is preferable. Moreover, although it is possible to issue certificates for many parts of the value chain (including middlemen and transport), the process becomes complicated when the value chain is long and there is the risk of double-counting or that some process steps may be excluded. An example of the book-and-claim system is the Renewable Energy Certificate System (RECS) in Europe.

There is also the opportunity of mass-balance. As in the book-and-claim approach, no separation is carried out. In the mass-balance approach certificates and products are sold together and there is no need for an issuing body. This means that the companies in the value chain are responsible for the balancing themselves. No company can sell more certified products than it has obtained. Sometimes, the system also includes the possibility of tracing back production to the country/ region of origin. The implementation costs of this system are typically lower than for the physical separation system, although each company will have costs arising from the additional accounting. It also has the advantage over the book-and-claim system that no issuing body is required (Dehue et al., 2007).

TABLE 3.7 - CERTIFICATION COST FOR PALM OIL RSPO SUPPLY CHAIN SYSTEMS

1. 'Segregated'	2. 'Mass Balance'	3. 'Book and Claim'
RSPO membership: < 500 MT/yr: € 100 > 500 MT/yr: € 2 000 • Supply chain certification (one audit/year) • CSPO premium including - USD 3/MT administrative costs - USD 1/MT contribution to RSPO	• RSPO membership: < 500 MT/yr: € 100 > 500 MT/yr: € 2 000 • Supply chain certification (one audit/year) • CSPO premium including - USD 3/MT administrative costs - USD 1/MT contribution to RSPO	• GreenPalm membership: USD 500 - or RSPO membership • Claim validation audit/year (one in ten end-users) • Certificates purchase price including - USD 3/MT administrative costs - USD 1/MT contribution to RSPO

Source: RSPO (2011)

In the case of bioenergy, different verification systems are currently under discussion. The EU RED mentions the mass-balance system as a starting point, but is open to the use of other methods (EP, 2008b). In contrast, private initiatives such as SEKAB's "Verified Sustainable Ethanol" are frequently based on physical segregation. As mentioned above, consumers often perceive this system as more reliable. Further, since the parties involved in the supply chain are generally low (SEKAB, for example, imports certified ethanol from five producers all concentrated in the São Paolo area in Brazil), the administrative costs connected with the model can be kept down. Upstream certification schemes (e.g. for feedstock) are also likely to have an impact on the choice.

3.5 Harmonization of certification schemes

The majority of the already implemented standards have been intended for the food or forest sector. Accordingly, the focus has been on local management rather than global impacts such as the greenhouse effect and food security. As new schemes are created to approach the wider scope of sustainable bioenergy, most of them contain both new principles and principles that are already included in existing standards. One idea under discussion is to establish a global, generic standard. To obtain such a meta-standard, producers comply with other standards that have been assessed as qualifying. This way, synergies and overlaps between different certification systems can be used to create a common system (Kaphengst et al., 2009). A SAN or RSPO certificate, for instance, can be used to verify compliance with some of the sustainability criteria of the UK standard.[32]

There are many advantages to a meta-standard. Primarily, it is a way to avoid redundant schemes and so to reduce the costs of administration. Further, existing schemes are already known among producers and the acceptance might be higher. For consumers, too many certification schemes can be puzzling. It also reduces the time needed to implement the new standard.

On the other hand, there is a rather high administrative cost of coordinating potential qualifying standards with the meta-standard. Moreover, many existing standards are more detailed than the meta-standard. Especially for small-scale producers, compliance with those stricter criteria might involve high costs. For some commodities such as Jatropha, no standards are currently in use. This could be a bottleneck for Jatropha biodiesel providers. Likewise, as has been pointed out above, some factors are not covered by the single feedstock schemes, such as global warming impact, food security and land use change (Dehue, 2007).

3.6 Conclusions: Strengths and limitations of biofuel certification schemes

In summary, biofuel and biomass certification schemes that emerged over recent years all aim to transform business practices by developing more responsible production, sourcing and manufacturing practices for a given sector or product. In principal, certification schemes do have an impact on supply chains and can critically re-orient decisions about the depth of corporate social responsibility. Some positive impacts for business include improved efficiency within a supply chain (e.g. better managed processes, higher production and quality, cost savings), decreased risk, higher transparency and increased awareness about problems in the supply chain. However, certification schemes, to the extent that they are established to control imports, can hinder trade and reduce market access – especially for developing countries with comparative advantages in

[32] For more information on standards accepted by the RTFO as 'qualifying', see van Stappen (2009).

business production, and which see in this industry a real opportunity for development and for overcoming rural poverty and high unemployment.

Despite the multiplicity of forms (e.g. roundtables, consortia, private labels, industry-wide certificates) and the varying sets of principles, criteria and indicators emphasized, the majority of these certification schemes fall under one type of certification governance: voluntary, market-based, industry-led, multistakeholder schemes. This development brings its own advantages, but it also presents limitations and raises issues.

While most certification schemes and scorecards articulate a range of principles and criteria on sustainability, the real challenge is implementation on the ground. There are inherent problems with identifying measurable, permanent impacts of certification schemes. Among these is often the lack of available and meaningful data that enable proper comparison and assessment of compliance. The second challenge comes from the necessity to leave the detailed minimum thresholds required under the stated principles and criteria to local conditions and local stakeholders, resulting in a wide range of compliance or adherence possibilities. Moreover, the principles and criteria themselves can be too broadly stated (with few exceptions), leading to a wide range of interpretations and a wide scope for adherence and reliability of the outcome.

On the social side, the impact of these certification schemes remains poorly documented, owing in large part to the wide range of social implications, their links with existing social policies, initiatives and practices (e.g. labour structure, types of land ownership, local resource management). Another reason is the highly location-specific context of social impacts. While the enactment of certification schemes may have some positive impacts on workers and local communities, there is still limited evidence of direct poverty-related impacts or improved food security and livelihoods – cross-cutting metrics that are poorly specified in most existing principles and criteria of current certification schemes.

Another limitation of the existing biofuel certification schemes is the concern that small-scale farmers are left out of these biofuel developments because of the dominant governance structure of these certifications led by large-scale agro-industry and the cost structure of certification, which is out of reach for most smallholders. One consequence is that these certification schemes result in a sort of a coalition of the active as opposed to being truly inclusive (UNCTAD, 2008). Consequently, as structured, these schemes would tend to favour big players and provide incentives for scaling up production to absorb the certification costs. Though there are incentives to address prohibitive certification costs for smallholders by some of the leading feedstock roundtables, a more sustainable solution is to ensure a more balanced representation of these roundtables with active participation of smallholders' representatives in these multistakeholder certification schemes.

Overall, the relationship between biofuels and sustainability is complex because of a number of factors which makes it difficult to address the key sustainability dimensions in an integrated manner. One complicating factor is the multiple uses of biomass (e.g. food, feed, fibre and now, fuel) while the sustainability requirement is currently limited to one type of use (i.e. biofuel). A certification scheme established on the basis of a single final use (i.e. biofuel) may be ineffective in securing sustainability (Paiano et al., 2011), resulting in indirect displacement effects. One remedy is to focus on sustainability at the biomass production side. Another problem stems from the indirect effects of biofuel sustainability because of market linkages between commodities in terms of land use and final-use substitution (e.g. feed demand and substitution between different crops and by-products). This requires a more complex monitoring system of the effects of biofuels at the global level. Finally, while the rising number of certification schemes could generate positive pro-competitive effects (in terms of improvements in implementation and verification tools), it could nevertheless lead to confusion and inconsistency, thus lowering the confidence of consumers and final users and lessening the effectiveness of these certification schemes.

What are the factors that could limit the implementation of biofuel certification schemes? Some of these will be discussed below. First, mandatory frameworks (such as the European Union Renewable Energy Directive) need to be consistent with international trade rules. Restrictions, be they economic, environmental or social, still need to comply with WTO rules and country Most Favoured Nation (MFN) commitments. As was discussed in Chapter 2, the classification of biofuels for transport is still unclear. This raises problems for the introduction of subsidy programmes and tariffs tied to sustainability schemes. Further, according to Article XX of GATT, a country cannot draw a distinction between domestic and imported products. In other words, domestically produced biodiesel should meet the same standards required of foreign producers (Fehrenbach et al., 2008). For example, Germany wanted to prohibit the importation of biodiesel out of palm oil and soy until effective sustainability could be demonstrated (van Stappen, 2009). However, the country had to modify the original draft proposal because the European Commission contested whether it was in line with the WTO/GATT (The Bioenergy Site News Desk, 2009).

A second constraint relates to the difficulty in quantifying impacts of biofuels. As a result, many of the sustainability standards currently under discussion lack measurable indicators. For example, Delzeit and Holm-Müller (2009) referred to the indicator "All workers receive minimum wages"; however, in many developing countries informal employment is widely practised, particularly in the agricultural sector. If no formal contracts exist, compliance with this indicator might be difficult and costly to assess.

Third, many developing countries express concern that certification schemes can become indirect trade barriers when not managed properly. For instance, European producers will find it easy to comply with the demand for education opportunities for employed farmers, while it could become a substantial cost for small-scale producers in a developing country (Delzeit and Holm-Müller, 2009). Meissner and Schukat (2009) arrived at a similar conclusion when reviewing the Dutch testing framework for sustainable biomass in Mozambique. They found that many larger companies already keep records needed for the audits, but that small-scale farmers often keep information on yields, fertilizers, by-products, etc. (i.e. data that is needed for the GHG estimations) in their memories rather than on paper. In addition, interviews with producers revealed that the exclusion of land with high carbon stock and biodiversity might be perceived as castigation for those who have not had the means to convert their land earlier.

A related issue refers to the adequacy of including global requirements in the certification schemes. For example, it may be questioned whether single farmers should be held responsible for rising food prices, as food prices depend on a number of factors. In the same way one could also ask if it is adequate to put restrictions on biofuel production but not on other final uses of the feedstock (such as food production).

Certification schemes mostly focus on the part of the production which enters international trade. It is unclear whether and how meta standards influence local production, sourcing and manufacturing practices for those commodities of which a significant part is produced and consumed domestically, or where local food standards may not require stringent sustainability requirements (e.g. sugar in India, palm oil in Indonesia and beef in Brazil).

Certification schemes are resource-intensive, resulting in differentiated participation in favour of large-scale agro-business, leaving out small-scale producers. Even so, the certification process makes high demands on initial investments, and this is challenging above all for small-scale producers. As was pointed out in the assessments of sustainable soy in Brazil and Jatropha in India, the smallholders generally have a good knowledge of on-farm conservation, but not the same options to extend native vegetation buffer zones. Similarly, field burning – among others an important emitter of greenhouse gases – is mainly practised on small farms, while many large plantations have mechanized their production.

To increase certification uptake, governments and international organizations in consumer and producer countries should establish complementary mechanisms to create an enabling environment. Such mechanisms could include national legislation, public procurement policies, tax incentives and tax relief and start-up grants. Financial institutions also have an important role to play to support and enable schemes.

These reservations make it clear that certification schemes will not have the weight to solve all problems related to biofuels sustainability. Rather, a mix of policy measures and market mechanisms are needed to encounter the challenge of reconciling different priorities and targets.

The fast growth of biofuel production in industrialized economies in the last decade has been largely driven by supportive policies in the form of mandates and subsidies. The widespread interest, investments and policies to encourage biofuels in both industrialized and developing countries mean a larger role for biofuel trade. Many developing countries have good potential to become biofuel producers and, in some cases, exporters as well. A crucial condition, not only for starting up a biofuel production but also for participating in international trade, would be appropriate policies and strategies by the national governments in cooperation with the private sector. Yet, in order to achieve this, access to functioning institutions (e.g. laws, policies, enforcement mechanisms), technologies and know-how are needed.

In general, the biofuel certification schemes that emerged in recent years have concentrated on three feedstocks for biofuels, namely sugar cane, oil palm and soybeans. These are important biofuel feedstocks with strong trade implications, which suggests that market is one of the main drivers for the "sustainability" requirements. Incidentally, no equivalent roundtable or multistakeholder certification scheme exists specifically for corn- another major ethanol feedstock, given that corn-ethanol coincide mostly with the USA, which produced ethanol first and foremost to meet domestic demand. The latter point is another indicator that trade considerations drive the current certification and sustainability developments for biofuels.

Certification schemes lack evidence of full participation by smallholders. Such schemes are, by design, data- or information-intensive and require added costs and capacity that is often beyond the reach of small-scale farmers. One way to reduce costs is to promote local inspection bodies; these involve lower costs for the producers, are better able to conduct spontaneous examinations and are generally better informed about on-site characteristics (Rundgren, 2007).

Further, because information exchange is straightforward, it may be easier to build greater confidence among local producers. Nonetheless, initial difficulties in gaining international trust, overcoming the high investment costs and lack of experience may pose serious entry barrier problems. Accordingly, there are still very few inspection bodies in sub-Saharan Africa, for example.

In some of the cases reviewed, certification schemes are particularly attractive if they result in high price premiums (e.g. coffee); however, this is not the case for biofuels, a bulk and fungible commodity. Moreover, the quasi-mandatory requirements for biofuel (or biomass) exports to the EU also remove the conditions for price premiums. On the other hand, in view of the limited access to land in Europe and the relatively low productivity of many feedstocks grown in this region, producers from developing countries may still be able to compete with European producers in spite of higher certification costs.

Most of the certification schemes do not properly address social sustainability as examined in Chapter 2. In most of the certification schemes, scorecards, etc., social dimensions tend to revolve around a few high-visibility concerns such as child labour, minimum wage, etc., typically all couched into adherence to national or international laws and regulations. However, other complex social factors such as participatory processes, common management of resources, health implications and other poverty-reduction or livelihood-enhancing measures are not typically addressed by such schemes. Moreover, the concern that these certification schemes seem to leave behind small-scale farmers also points out the weak link between these certification schemes and their social implications. It is not clear that certification schemes are the best vehicle to impose social norms. Scorecards or FAO's guidelines on land tenure are more appropriate to ensure the mitigating effects of biofuel development projects.

To sum up, this review addressed the advantages and limitations of biofuel certification. There are positive, negative and mixed impacts of biofuel certification, depending on the case. Environmental impacts for certification (e.g. FSC) can bring positive benefits if they facilitate forest planning and inventory, silviculture, biodiversity protection and monitoring and compliance. Economic impacts can also be positive if certification can generate price premiums above certification costs for suppliers, ensure decent wages to workers and guarantee market access. On the downside, there are negative effects on smallholders who appear to be left out of the certification schemes.

Many other questions remain to be tackled. For example, how should issues such as food security and indirect land-use change (or even direct land-use change) be approached? Is the current voluntary industry-led structure of certification schemes the best way to ensure sustainability and its various dimensions? Are there implications for a stronger regulatory role and greater inclusion of small-scale producers in developing countries? Are these issues best addressed within international fora such as the RSB or GBEP? Is there a need for new mechanisms? Should there be small-scale-specific certification schemes, especially those that focus on community-level microbioenergy or renewable energy projects that are more suitable for small-scale agriculture? Are certification schemes the best way or are there other better mechanisms (e.g. enforcement of national laws, transfers from developed countries to developing countries to compensate for maintaining rain forests, integration of biofuel projects in the carbon emission trading scheme)?

Beyond these questions biofuel development is also facing up with increasing urgency the rising challenges of climate change and the need to account for carbon balances more specifically leading to such as concepts as carbon footprints and consequently to carbon certification. How should the initial concern of biofuel certification schemes integrate or include carbon certification or are these two separate concerns? Are the social criteria of these existing certification schemes compatibles with the recently endorsed Voluntary Guidelines on the Responsible Governance of Tenure of Land, Fisheries in the Context of National Food Security (FAO, 2012b)? Are these voluntary guidelines comptables with existing principals and criteria in certification schemes; if not would the latter have to be adjusted to adhere to these guidelines which are more broader and affect agricultural systems beyond biomass-biofuels?

References

Achten, W., Mathijs, E., Verchot, E., Singh, V., Aerts, R. & Muys, B. (2007). Jatropha biodiesel fueling sustainability? Biofuels, Bioproducts & Biorefining 1(4): 283–291.

Aden, A. (2007). Water Usage for Current and Future Ethanol Production. Southwest ydrology September/October, 22-23.

ADM. (Archer Daniels Midland Company, 2009). ADM Announces Partnership with Aliança Da Terra to Encourage Sustainable Soy Farming in Brazil. Retrieved June 24, 2009, from http://www.adm.com/en-US/news/_layouts/PressReleaseDetail.aspx?ID=39.

Agus, F., Suyanto, W. & van Noordwijk, M. (2007). Reducing emissions from Reducing Emission from Peatland Deforestation and Degradation: Carbon Emission and Opportunity Costs. International Symposium and Workshop on Tropical Peatland. Carbon - climate - human interaction - carbon pools, fire, mitigation, restoration, and wise use. Yogyakarta, Indonesia, 27-31 August 2007.

Altenburg, T., Dietz,H., Hahl, M., Nikolidakis, N., Rosendahl, C. & Seelige, K. (2009). Biodiesel in India Value chain organisation and policy options for rural development. Bonn: DIE – (Studies/Deutsches Institut für ntwicklungspolitik ; 43).

Amatayakul, W. & Berndes, G. (2007). Fuel ethanol program in Thailand: energy, agricultural, and environmental trade-offs and prospects for CO2 abatement. Energy for Sustainable Development XI(3): 51-66.

Amigun, B., Sigamoney & Von Blottnitz, H. (2008). Commercialisation of biofuel industry in Africa: A review. Renewable and Sustainable Energy Reviews 12(3): 690-711.

Amoah, O. (2006). Jatropha project in Ghana: how to restore vegetation and ecosystem along major man made lakes and ways to raise finance. Paper presented at the Regional workshop on financing biofuels and Jatropha plantations projects with special emphasis on Clean Development Mechanisms in Accra, Ghana, November 13–14. Retrieved June 26, 2009, from http://www.unctad.org/Templates/Meeting.asp?intItemID=2068&lang=1&m=12952&year=2006&month=1.

Amsallem, I., Wilkie, M., Koné, P. & Ngandji, M. (2003). Sustainable management of tropical forests in Central Africa. FAO Forestry Paper 143. Food and Agriculture Organization of the United Nations (FAO).

Armstrong, A., Baro, J., Dartoy, J., Groves, A., Nikkonen, J., Rickeard, D., Thompson, N. & Larivé, J. (2002). energy and greenhouse. gas balance of biofuels for europe - an update. concawe, report no. 2/02: Brussels.

Asal, S., Marcus, R. & Hilbert, J. (2006). Opportunities for and obstacles to sustainable biodiesel production in Argentina. Energy for Sustainable Development X(2): 48-58.

Bach, O. (2009). Sustainable Agriculture Network Standards for Sugar cane & Oilpalm Plantations. Presentation held at Sustainable Agriculture & Biofuels Certification Forum, World Biofuel Markets Congress, in Amsterdam, March 16.

Barrett, H., Browne, A., Harris, P. & Cadoret, K. (2002). Organic certification and the UK market: organic imports from developing countries. Food Policy 27(4): 301-318.

Bauen et al. (2009). Modelling supply and demand of bioenergy from short rotation coppice and Miscanthus in the UK, Bioresource Technology.

Beckman, C. (2006). Biodiesel. Bi-weekly Bulletin 19(15). Retrieved April 28, 2009, from http://dsp-psd.pwgsc.gc.ca/Collection/A27-18-19-15E.pdf.

Bernesson, S., Nilsson, D. & Hansson, P. (2004). A limited LCA comparing large- and small-scale production of rape methyl ester (RME) under Swedish conditions. Biomass and Bioenergy 26 (6): 545-559.

Bernhard-Reversat, F. (Ed.) 2001. Effect of exotic tree plantations on plant diversity and biological soil fertility in the Congo savanna: with special reference to eucalypts. Center for International Forestry Research, Bogor, Indonesia.

Bevill, K. (2008). Tiger Ethanol announces new plan. Ethanol Producer Magazine. Retrieved June 9, 2009, from http://www.ethanolproducer.com/article.jsp?article_id=3653.

Bindraban, P. & Greco, F. (2008).The sustainability and resource use of soybean cultivation. In van Berkum, S. and P. Bindraban (Eds.). Towards sustainable soy. An assessment of opportunities and risks for soybean production based on a case study Brazil. Report 2008&080. LEI Wageningen UR, The Hague.

Biopact. (2007). China launches rapeseed biodiesel initiative. Retrieved June 9, 2009, from http://news.mongabay.com/bioenergy/2007/03/china-launnches-rapeseed biodiesel.html.

BMU. (Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit, 2007). "Preface to the regulation requirements for the sustainable production of biomass for use as biofuels (Biomass Sustainability Regulation—BioNachV)." Bonn, Germany: Bundesministeriums für Umwelt.

BNDES & CGEE. (Brazilian National Bank for Economic and Social Development and the Center for Strategic Studies and Management, 2008). Sugar cane-based bioethanol : energy for sustainable development. 1st Edition. Rio de Janeiro.

Bradley, D., Diesenreiter, F. & & Tromborg, E. World Biofuel Maritime Shipping Study. For IEA Bioenergy Task 40. April 15. Retrieved July 05, 2009, from http://www.bioenergytrade.org/fuelmaritimeshippingstudyapril152009.pdf

Brittaine, R. (2008). SUSTAINABLE BIOFUEL PRODUCTION BY SMALL FARMERS WITH REFERENCE TO JATROPHA AND SWEET SORGHUM. Dissertation prepared in partial fulfilment of the requirements for the Degree of Master of Science (MSc.) in Tropical Agricultural Development, University of Reading.

Brooker, I. (2002). Botany of the eucalyptus. In Coppen, J. Eucalyptus: The Genus Eucalyptus.

Bundesregierung. (2008). Bericht der Bundesregierung zur Öl- und Gasmarktstrategie.

Caminiti, M., Cassal, M., OhEigeartaigh, M. & Zeru, Y. (2007). Feasibility Study of Biofuel Production in Ghana: Assessing Competitiveness and Structure of the Industry's Value Chain. Final report. Elliott School of International Affairs - The George Washington University.

Campinhos, E. (1999). Sustainable plantations of high-yield Eucalyptus trees for production of fiber: the Aracruz case. New Forests17(1-3): 129–143.

Carriquiry, M. (2007). U.S. Biodiesel Production: Recent Developments and Prospects. Iowa Ag Review 13(2): 8-11.

Cartwright, A. (2007). Biofuels trade and sustainable development: An analysis of South African bioethanol. Working Document December. International Institute for the Environment Development (IIED).

Cattanach, A., Dexter, A. & Oplinger, E. (2000). Sugar beets. Alternative Field Crops Manual. Retrieved June 9, 2009, from http://www.hort.purdue.edu/newcrop/AFCM/sugar beet.html.

CEO (Corporate Europe Observatory) http://www.corporateeurope.org/sugar-cane-ethanol-not-so-sweet

Chaturvedi, P. (2009). Email communication May 28.

Chong, Wong at al. (1998) Performance of different micro algal species in removing nickel from industrial wastewater. International Conference on Environmental Contamination Toxicology and Health, Hong Kong, 23-25 September 1998.

CIAT. (International Center for Tropical Agriculture, 2001). Cassava: A Crop for Hard Times and Modern Times. CIAT in Focus. Retrieved March 25, 2009, from http://www.ciat.cgiar.org/ciatinfocus/cassava.htm.

Clay, J. (2004). World Agriculture and the Environment - A Commodity-by-Commodity Guide to Impacts and Practices. World Wildlife Fund.

Cleantech Group LLC. (2008). India can't use own biodiesel. October 8. Retrieved June 29, 2009, from http://www.cleantech.com/news/3661/india-already-shipping-biodiesel-us-eu.

Coelho, S. (2005). Biofuels – Advantages and Trade Barriers. UNCTAD February, 4. UNCTAD/DITC/TED/2005/1.

Coppen, J. (2002). Eucalyptus: The Genus Eucalyptus. Taylor & Francis: London.

Corsi, S., Friedrich, T., Kassam, A., Pisante, M. & de Moraes Sà, C. (2012): Soil Organic Carbon Accumulation and Greenhouse Gas Emission Reductions from Conservation Agriculture: A literature review, Integrated Crop Management Vol.16-2012, AGP/FAO, Rome, 101 pp.

Cossalter, C. & Smith, C. (2003). Fast wood Forestry: Myths and Realities. Center for International Forestry Research (CIFOR): Jakarta.

Coyle, W. (2007). The Future of Biofuels, a Global Perspective. Amber Waves 5(5): 24-29.

CRA (Canada Revenue Agency), http://www.cra-arc.gc.ca/menu-eng.html

Dankers, C. (2003). Environmental and Social Standards, Certification and Labelling for Cash Crops. Food and Agricultural Organization of the United Nations. Rome.

de Fraiture, C. (2007). Biofuel crops could drain developing world dry. Science and Development Network. Opinions, 10 May. Retrieved May 6, 2009, from http://www.scidev.net/en/opinions/biofuel-crops-could-drain-developing-world-dry.html.

de Fraiture, C. & Berndes, G. (2009). Biofuels and Water. *In* Howarth, R. and S. Bringezu (eds). Biofuels: Environmental Consequences and Interactions with Changing Land Use. Proceedings of the Scientific Committee on Problems of the Environment (SCOPE) International Biofuels Project Rapid Assessment, 22-25 September 2008, Gummersbach, Germany. 139-152.

de Oliveira, M., Vaughan, B. & Rykiel, E. (2005). Ethanol as Fuel: Energy, Carbon Dioxide Balances, and Ecological Footprint. BioScience 55(7): 593-602.

De Schutter, O. 2009. Large-scale land acquisitions and leases: A set of core principles and measures to address the human rights challenge. Report issued by the United Nations Special Rapporteur on the right to food, 11 June 2009.

Dehue, B., Meyer, S & Hamelinck, C. (2007). Towards a Harmonised Sustainability Biomass Certification Scheme. PBIONL072413. Ecofys Netherlands.

Deininger, K. & Byerlee, D. 2010. *Rising global interest in farmland: Can it yield sustainable and equitable benefits?* Washington, D.C.: World Bank.

Delzeit, R. & Holm-Mueller, K. (2009). Steps to discern sustainability criteria for a certification scheme of bioethanol in Brazil: Approach and difficulties. Energy 34(5): 662-668.

Devissher, T. (2007). The Effects of Palm Oil Biodiesel in Producer Developing Countries: A Case Analysis of Malaysia Linking National Perspectives with Ground Realities. Thesis for the fulfilment of the Master of Science in Environmental Sciences, Policy & Management Lund, Sweden, June.

Digman, B., Soo Joo, H. & Kim, D. (2009). Recent Progress in Gasification/Pyrolysis Technologies for

dos Santos, M. (1998). Energy Analysis of Crops Used for Producing Ethanol and CO2 Emissions. Proceedings of the third Biomass Conference of the Americas, Montreal, 24 – 29 August 1997.

dos Santos Silva, M., Camara, G. Escada, M. & De Souza, R. (2008). Remote-sensing image mining: detecting agents of land-use change in tropical forest areas. International Journal of Remote Sensing 29(16): 4803-4822.

Draycott, P. (Ed.). (2006). Sugar Beet. Wiley-Blackwell Publishing: Harayana.

Dufey, A. (2006). "Biofuels production, trade and sustainable development: emerging issues." Sustainable Markets Discussion Paper Number 2. International Institute for Environment and Development, November.

Durst, P., Mckenzie, P., Brown C. & Appanah, S. (2006). Challenges facing certification and ecolabelling of forest products in developing countries. International Forestry Review 8(2): 193-200.

EC. (European Commission, 2009). CAP reform - a long-term perspective for sustainable agriculture. Agriculture and Rural Development. Retrieved July 4, 2009, from http://ec.europa.eu/agriculture/capreform/index_en.htm.

Ecocrop. (2009). Ecocrop database.

Econergy International Corporation. (2008). Mozambique Biofuels Assessment. FINAL REPORT. Ed. George Huber Diagram of Routes to Make Biofuels; NSF. 2008. Breaking the Chemical and Engineering Barriers to Lignocellulosic Biofuels: Next Generation Hydrocarbon Biorefineries.

EEA. (European Environment Agency, 2006). How much bioenergy can Europe produce without harming the environment? EEA Report No 7/2006. Retrieved June 9, 2009, from http://www.eea.europa.eu/publications/eea_report_2006_7/at_download/file.

EEG. (Erneuerbare-Energien-Gesetz, 2008). Gesetz zur Neuregelung des Rechts der Erneuerbaren Energien im Strombereich und zur Änderung damit zusammenhängender Vorschriften. October 25. Retrieved June 23, 2009, from http://www.bgblportal.de/BGBL/bgbl1f/bgbl108s2074.pdf.

Elbehri, A. (2008). The Economics of Biomass Feedstocks in the United States: A Review of the Literature. Biomass Research and Development Board. Occasional Papers Report No. 1.

Elbehri, A., Umstaetter, J. & Kelch, D. (2008). The EU Sugar Policy Regime and Implications of Reform. USDA. Economic Research Report Number 59.

Elbersen, H., Bindraban, P., Blaauw, R. & Jongman, R. (2008). Biodiesel from Brazil. Report for the Dutch Ministry of Agriculture, Nature and Food Quality. Report BO-CI-35.

EP. (European Parliament, 2008a). MEDDELANDE TILL LEDAMÖTERNA. CM\729457SV.doc. PE407.952v01-00. - (2008b). Promotion of the use of energy from renewable sources. COM(2008)0019 – C6-0046/2008 – 2008/0016(COD). Retrieved April 21, 2009, from http://www.europarl.europa.eu/sides/getDoc.do?pubRef=//EP//TEXT+TA+P6TA20080609+0+DOC+XML+V0//EN&language=EN#BKMD-1.

Escobar, J., Lora, E., Venturini, O., Yáñez, E., Castillo, E. & Almazan, O. (2009). Biofuels: Environment, technology and food security. Renewable and Sustainable Energy Reviews 13(6-7): 1275-1287.

Essent. (2007). Green electricity from coffee husks. Retrieved June 24, 2009, from http://www.essent.eu/content/about_essent/news/archive/green_electricity_from_coffe e_husks.jsp.

Etanolverde. (2009). Environmental Directives of Sugar Cane Sector Protocol (Guidelines). Retrieved June 23, 2009, from http://homologa.ambiente.sp.gov.br/etanolverde/guidelines.asp.

EUBIA. (European Biomass Industry Association, 2007). Biomass Pelleting. Retrieved April 23, 2009, from http://www.eubia.org/111.0.html.

European Commission. - Methodology for GHG calculation set by the Renewable Energy Directive (European Commission - Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources

European Commission Information Research Centre. (2009). Greenhouse gases. Retrieved April 28, 2009, from http://ec.europa.eu/research/infocentre/article_en.cfm?id=/research/researcheu/earth/article_earth30_en.html&item=Infocentre&artid=10423.

EurActiv. (2008). Biofuels, Trade and Sustainability. Retrieved April 23, 2009, http://www.euractiv.com/en/trade/biofuels-trade-sustainability/article-171834.

Evans, J. & Turnbull, J. (2004). Plantation Forestry in the Tropics. 3rd Edition. Oxford University Press: New York.

Facius, J. & Ipsen, I. (2006). Major changes in land use and their consequent impact on the livelihoods of villagers in Nong Mai Daeng. SLUSE Report 10.04.06. Retrieved June 9, 2009, from http://www.sluse.life.ku.dk/Courses/ILUNRM/~/media/ljv/SLUSE/ILUNRM/reports/06_NongMaiDaeng.ashx.

FairMatch Support. (2009). Portal for Codes, Standards and Certification Systems. Retrieved August 11, 2009, from http://www.fairmatchsupport.nl/documents-certification-details.php?id=3.

FAO. (Food and Agricultural Organization of the United Nations, 2001). The global cassava development strategy and implementation plan. Volume 1. Proceedings of the Validation on the Global Cassava Development Strategy. Rome, 26-28 April 2000. Reprinted 2004.

- (2004). Fertilizer use by crop in Malaysia. Land and Plant Nutrition Management Service Land and Water Development Division.
- (2003). *Trade Reforms and Food Security*. Rome.
- (2007a). Food Outlook June 2007.
- (2007b). ITEM 5: Global Wood and Wood Products Flow Trends and Perspectives. Proceedings from the FAO Advisory Committee on Paper and Wood Products Forty-eighth session. Retrieved July 2, 2009, from http://www.fao.org/forestry/media/12711/1/0/.
- (2008a). The State of Food and Agriculture 2008.
- (2008b). Food Outlook November 2008.
- (2008c). Forests and Energy. Key Issues. FAO Forestry Papers 154.
- (2009a). FAOSTAT.
- (2009b). Crop Water Information: Sugar cane. Retrieved June 9, 2009, from http://www.fao.org/nr/water/cropinfo_sugar cane.html.
- (2009c). FAO Country Profiles: Mozambique.
- (2009d). Food Outlook June 2009.
- (2009e). FAO Country Profiles: Argentina.
- (2009f). FAO Country Profiles: Ghana.
- (2009g). Algae-based Biofuels: A Review of Challenges and Opportunities for Developing Countries. FAO, Rome.
- (2010a). Jatropha: A Smallholder Bioenergy Crop The Potential for Pro-Poor Development, by Britaine R. and N. Lutaladio, Integrated Crop Management Vol. 8–2010.
- (2010b). Making Integrated Food-Energy Systems Work for People and Climate An Overview, by: A. Bogdanski, O. Dubois, C. Jamieson, and R. Krell. Environment and Resource Management Working Paper No.45, FAO Rome.
- (2010c). Integrated Food-Energy Systems. Project assessment in China and Vietnam, Bogdanski, A., O. Dubois, and D. Chuluunbaatar , D. October 2010. Final Report. FAO, Rome.

- (2011a). The State of the World's land and Water Resources for Food and Agriculture: Managing systems at Risk. FAO, Rome.
- (2011b). The Global Bioenergy Partnership Sustainability Indicators for Bioenergy; First edition; December 2011
- (2011c). Smallholders in Global Bioenergy Value Chains and Certification –Evidence from Three Case Studies, E. Beall, editor. Environment and Natural Resources Working Paper No.50 – FAO, Rome.
- (2012a). Good Environemental Practices in Bioenergy Feedstock Production: Making Bioenergy Work for Climate and Food Security. Edited by Andrea Rossi. Environnmental and Natural Ressources Working Paper No. 40. FAO, Rome, 2012.
- (2012b). Voluntary Guidelines on the Responsible Governance of Tenure of Land, Fisheries and Forests in the Context of National Food Security. Committee on Food Security, FAO Rome.

Fapri (Food and Agricultural Policy Research Institute). (2011). FAPRI U.S. and world agricultural outlook. University of Missouri and Iowa State University. Available online: http://www.fapri.iastate.edu/outlook/

Fischer, G., Teixeira, E., Tothne Hizsnyik, E. & van Velthuizen, H. (2008). Land use dynamics and sugar cane production. In "Sugar cane ethanol. Contributions to climatechange mitigation and the environment". Zuurbier, P. and J. van de Vooren (Eds.).Wageningen: Wageningen Academic Publishers.

Fitzherbert, E., Struebig M., Morel A., Danielsen F., Bru C., Donald P. & Phalan, B. (2009) "How will oil palm expansion affect biodiversity?," *Trends in Ecology and Evolution* Vol.23 No.10

FSC. (2012). Global FSC certificates: type and distribution. Forest Sustainability Council, May 2012

Fargione, J., Hill, J., Tilman, D., Polasky, S. & Hawthorne, P. (2008). Land Clearing and the Biofuel Carbon Debt. Science 319(5867): 1235 – 1238.

Farrell, A., Plevin, R., Turner, B., Jones, A., O'Hare, M. & Kammen, D. (2006). Ethanol Can Contribute to Energy and Environmental Goals. Science 311(5760): 506 – 508.

Fehrenbach, H. (2009). Wirtschaftlichkeitsanalyse eines Massebilanz-Zertifizierungssystems für Palm- und Sojaöl. ifeu Institut für Energie- und Umweltforschung.

Fehrenbach, H., Giegrich, J., Reinhardt, G., Sayer, U., Gretz, M., Lanje, K. & Schmitz, J. (2008). Criteria for Sustainable Bioenergy Use on a Global Scale. ifeu Institut für Energie- und Umweltforschung. R+D project no. 206 41 112 on behalf of the Federal Environment Agency Dessau-Rosslau.

Fermont, A., van Asten, P., Tittonell, P., van Wijk, M. & Giller, K. (2009). Closing the cassava yield gap: An analysis from smallholder farms in East Africa. Field Crops Research 112(1): 24-36.

FIAN International. (2010). Land grabbing in Kenya and Mozambique. A report on two research missions – and a human rights analysis of land grabbing, FIAN, April 2010.

Fischer, G., Teixeira, E., Tothne Hizsnyik, E. & van Velthuizen, H. (2008). Land use dynamics and sugar cane production. In "Sugar cane ethanol. Contributions to climatechange mitigation and the environment". Zuurbier, P. and J. van de Vooren (Eds.).Wageningen: Wageningen Academic Publishers.

Fogarty, D. (2009). Palm oil buyers face green scorecard: WWF. Reuters, May 12. Retrieved June 29, 2009, from http://www.reuters.com/article/GCA-GreenBusiness/idUSTRE54B02T20090512.

(2008a). Sustainability as a smokescreen. The inadequacy of certifying fuels and feeds. Retrieved June 24, 2009, from http://www.foe.co.uk/resource/reports/smokescreen.pdf.

- (2008b). fuelling destruction in latin America the real price of the drive for agrofuels. Issue 113, September. Retrieved June 29, 2009, from http://www.foei.org/en/publications/pdfs/biofuels-fuelling-destruction-latinamerica.
- (2008c). malaysian palm oil - green gold or green wash?. Issue 114, October.

FSC. (Forest Stewardship Council 2009a). Frequently asked questions about FSC. Retrieved August 11, 2009, from http://www.fsc.org/faq.html?&no_cache=1.
- (2009b). Small and Low Intensity Forest Management (SLIMF). Retrieved August 11, 2009, from http://www.old.fsc.org/slimf/.

Gallagher, P., Schamel, G., Shapouri, H. & Brubaker, H. (2006). The International Competitiveness of the US Corn-Ethanol Industry: A Comparison with Sugar-Ethanol Processing in Brazil. *Agribusiness* 22(1): 109–134.

GBEP. (Global Bioenergy Partnership, 2007). A review of the current state of bioenergy development in G8 +5 countries.
- (2008). inventory of current initiatives on sustainable bioenergy development. Retrieved June 24, 2009, from http://www.globalbioenergy.org/fileadmin/user_upload/gbep/docs/2008_events/2nd_TF_Sustainability/INVENTORY_draft_19.09.2008.pdf.

GBEP report to the G8 Deauville Summit 2011. http://www.globalbioenergy.org/fileadmin/user_upload/gbep/docs/GBEP_Report_to_the_G8_Summit_2011.pdf

Genetic ID. (2005). Feasibility Study on the Basel Criteria for Responsible Soy Production as prepared by ProForest in August 2004 for Coop Switzerland in cooperation with WWF Switzerland.

Gerbens-Leenes, P., Hoekstra, A. & van der Meer, T. (2009a). The water footprint of energy from biomass: A quantitative assessment and consequences of an increasing share of bio-energy in energy supply. Ecological Economics 68(4): 1052-1060.
- (2009b). The water footprint of bioenergy. PNAS 2009: 0812619106v1 pnas.0812619106.

German L. & Schoneveld G. (2011). Social sustainability of EU-approved voluntary schemes for biofuels: Implications for rural livelihoods, Center for International Forestry Research (CIFOR).

GEXSI. (The Global Exchange for Social Investment, 2008). Global Market Study on Jatropha. Final report. Prepared for the World Wide Fund for Nature (WWF).

GRAIN. (2011). http://www.grain.org/

Grassi, G., Tondi, G. & Helm, P. (2004). Small-Sized Commercial Bioenergy Technologies as an Instrument of Rural Development. In Organisation for Economic Co-operation and Development (OECD). Biomass and agriculture.

Griffee, P. (2000). Saccharum officinarum. Retrieved June 9, 2009, from http://ecoport.org/ep?Plant=1884&entityType=PL****&entityDisplayCategory=full.
- (2008). Elaeis guineensis Jacq. Retrieved June 23, 2009, from http://ecoport.org/perl/ecoport15.pl?searchType=entityDisplay&entityId=972.

Gnansounou, E., Panichelli, E., Dauriat, A. & Villegas, V. (2008). Accounting for indirect land-use changes in GHG balances of biofuels: Review of current approaches. GR-GN-WORKING-2008-002. École Polytechnique fédérale de Lausanne.

Goldemberg, J. & Guardabassi, P. (2009). Are biofuels a feasible option? *Energy Policy* 37(1): 10-14.

Goldemberg, J., Coelho, S. & Guardabassi, P. (2008). The sustainability of ethanol production from sugar cane. *Energy Policy* 36(6): 2086-2097.

Government of India. (2007), Report of the working group on Animal Husbandry and Dairying for the Eleventh Five Year Plan (2007-2012), Planning Commission, Delhi. Retrieved July 4, 2009, from http://planningcommission.nic.in/aboutus/committee/wrkgrp11/wg11_rpanim.pdf.

Green Car Congress. (2009). EU Action to Alter New German Biofuel Law. Retrieved June 23, 2009, from http://www.greencarcongress.com/2009/02/eu-action-to-al.html.

Groom M., Gray, E. & Townsend, P. (2007). Biofuels and Biodiversity: Principles for Creating Better Policies for Biofuel Production. Conservation Biology 22(3): 602–609.

Grote, U. (2009). Environmental Labeling, Protected Geographical Indications and the Interests of Developing Countries. The Estey Centre Journal of International Law and Trade Policy 10(1): 94-110.

Hadders, G. (2002). Pelletspärmen. Institutet för jordbruks- och miljöteknik. Retrieved April 23, 2009, from http://www.jti.se/uploads/jti/pelletsparmen.pdf.

Halleux, H., Lassaux, S., Renzoni, R. & Germain, A. (2008). Comparative life cycle assessment of two biofuels: Ethanol from sugar beet and rapeseed methyl ester. International Journal of Life Cycle Assessment 13(3): 184-190

Harrison, J., Tiwari, S. & von Maltitz, G. (2009). DEVELOPING A SUSTAINABILITY FRAMEWORK FOR ASSESSING BIOENERGY PROJECTS. Paper presented at the 17th European Biomass Conference in Hamburg July 1. Retrieved August 11, 2009, from http://www.ceg.ncl.ac.uk/reimpact/Related Documents/Reports/SustainabiltyPaper_HarrisonEtAl_09.pdf.

Hartemink, H. (2003). Soil Fertility Decline in the Tropics. With Case Studies on Plantations. CABI Publishing: Oxon.

Hettinga, W., Junginger, H., Dekker, S., Hoogwijk, M., McAloon, A. & Hicks, K. (2008). Understanding the reductions in US corn ethanol production costs: An experience curve approach. *Energy Policy* 37(1): 190-203.

Hill, J., Nelson, E., Tilman, D., Polasky, S. & Tiffany, D. (2006). Environmental, economic, and energetic costs and benefits of biodiesel and ethanol biofuels. *Proceedings of the National Academy of Sciences* of the United States of America (PNAS). 103(30): 11206-11210.

Hoh, R. (2008). Malaysia Bio-Fuels Annual 2008. 5/30/2008. GAIN Report Number: MY8018.

Howard, G. & Ziller, S. (2008). Alien alert – plants for biofuel may be invasive. Bioenergy Business July/August.

Howeler, R. (2002). Nutrient inputs and losses in cassava a-based cropping systems— Examples from Vietnam and Thailand. In: Proc. Intern. Workshop on Nutrient Balances for Sustainable Agricultural Production and Natural Resource Management in Southeast Asia, held in Bangkok, Thailand. Feb 20-22, 2001.

Howeler, R., Watananonta, W. & Ngoc Ngoan, T. (2005). Working with Farmers: The Key to Achieving Adoption of More Sustainable Cassava Production Practices on Sloping Land in Asia. Paper presented at UPWARD Network Meeting held in Hanoi, Vietnam, January 19-21.

Huay Lee, J., Rist L., Obidzinski K., Ghazoul J. & Koh L. (2011). "No Farmer left behind in sustainable biofuel production," Biological Conservation 144 (2011): 2512-2516.

ICRISAT. (International Crops Research Institute for the Semi-Arid Tropics, 2007). Pro-Poor Biofuels Outlook for Asia and Africa: ICRISAT's Perspective. A Working Paper. March 13. Retrieved June 25, 2009, from http://www.icrisat.org/Investors/Biofuel.pdf.
- (2009). ICRISAT's experiences on development and application of tools relevant to the sustainable production and use of biofuels. Retrieved June 23, 2009, from https://www.cbd.int/doc/biofuel/Bioversity%20ICRISAT-Report-Biofuels.pdf.

IEA. (International Energy Agency, 2004). BIOFUELS FOR TRANSPORT. An International Perspective. Retrieved March 25, 2009, from http://www.iea.org/textbase/nppdf/free/2004/biofuels2004.pdf. - International Energy Agency; http://www.iea.org/

- (2007a). World Energy Outlook 2007. Paris.
- (2010). Sustainable Production of Second Generation Biofuels Potential and perspectives in major economies and developing countries.
- (2011).Technology Roadmap, Biofuels for Transport.

IFAD. (International Fund for Agricultural Development, 2007). Summary Report of the "Global Consultation on Pro-Poor Sweet Sorghum Development for Biofuel Production and Introduction to Tropical Sugar Beet". 8-9 November 2007. Retrieved March 25, 2009, from http://www.ifad.org/events/sorghum/final.pdf.

IFP. 2012. "Panorama 2012: Biofuels update: growth in national and international markets" (IFP energies nouvelles).

IICA. (Instituto Interamericano de Cooperación para la Agricultura, 2007). Atlas de la agroenergía y los biocombustibles en las Américas: i.etanol. San José, Costa Rica.

Illegal Logging. (2009). Congo Brazzaville. Retrieved June 29, 2009, from http://www.illegal-logging.info/sub_approach.php?subApproach_id=69.

ILO. (International Labour Office, 2008). Inter-regional project: How to strengthen social protection coverage in the context of the European Union Agenda on decent work and promoting employment in the informal economy Thailand: A case study. Social Security Department. ILO/EU/Thailand/R.38. Retrieved June 9, 2009, from http://www.tdri.or.th/en/pdf/ilo-eu-thailand.r.38,%202008.pdf.

Inmetro. (Instituto Nacional de Metrologia, Normalização e Qualidade Industrial, 2009). Programa Brasileiro de Certificação em Biocombustíveis. in Developing Countries. Energy Sector Management Assistance Programme (ESMAP). Retrieved March 25, 2009, from http://www.esmap.org/filez/pubs/31205BiofuelsforWeb.pdf.

Instituto Brasileiro de Geografia e Estatística. (2008). Milho e soja fazem Brasil ter produção recorde de grãos em 2007. Retrieved June 24, 2009, from http://ibge.gov.br/home/presidencia/noticias/noticia_visualiza.php?id_noticia=1190&id_pagina=1.

InterAmerican Development Bank. Biofuels Scorecard; http://www.iadb.org/biofuelsscorecard/

IPCC. (Intergovernmental Panel on Climate Change, 2007). Mitigation of Climate Change. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge: Cambridge University Press.

ISEAL. http://www.isealalliance.org/content/about-us

ISSEAS. (2007). page 23

IWMI. (International Water Management Institute, 2008). Water implications of biofuel crops: understanding tradeoffs and identifying options. Water Policy Brief, Issue 30. Retrieved May 5, 2009, from http://www.iwmi.cgiar.org/Publications/Water_Policy_Briefs/PDF/WPB30.pdf.

Jabareen, Y. (2008). A New Conceptual Framework for Sustainable Development. Environment, Development and Sustainability 10(2): 179-192.

JGSEE. (The Joint Graduate School of Energy and Environment King Mongkut's University of Technology Thonburi, 2009). Report on Best Practices & Failures

- Thailand. In Second Periodic Activity Report (01.01.2008 – 31.12.2008). FP6-2004-INCO-DEV-3.

Johnson, F. (2007). Selected Results from the Thematic Research Network: Cane Resources

Network for Southern Africa (CARENSA). Presentation held at Project Meeting, 21 June 2007, Competence Platform on Energy Crop and Agroforestry Systems for Arid and Semi-arid Ecosystems – Africa (COMPETE). Retrieved June 9, 2009, from http://www.compete-bioafrica.net/events/events2/presentations_mauritius/first_meeting/S1-2-COMPETE-Meeting-Mauritius-21June2007-CARENSA-Johnson.pdf.

Johnson, F. & Matsika, E. (2006). Energy for Sustainable Development X(1): 42-53.

Johnston, M. & Holloway, T. (2007). A Global Comparison of National Biodiesel Production Potentials. Environmental Science & Technology 41(23): 7967–7973.

Jongschaap, R. (2008). A to Z of Jatropha Curcas L: 3. Agronomy. Plant Research International Wageningen UR. Retrieved July 4, 2009, from http://www.pri.wur.nl/NR/rdonlyres/90AF26A1-47D5-4F2F-9E96-D413C2933685/70109/JatrophaWorld2008Agronomy.pdf.

Jongschaap, R., Corré, W., Bindraban, P. & Brandenburg, W. (2007). Claims and facts on *Jatropha curcas L.*: global Jatropha curcas evaluation. breeding and propagation programme. Wageningen: Plant Research International. Report 158.

Jumbe, C., Msiska, F. & Mhango, L. (2007). Report on National Policies on Biofuels Sector Development in Sub-Saharan Africa. Final Working Draft. Food Agriculture and Natural Resources Policy Analysis Network (FANRPAN). December. Retrieved July 4, 2009, from http://www.fanrpan.org/documents/d00462/COMPETE_National_Policies_Biofuels_Dec2007_draft.pdf.

Kaditi, E. (2008). Bio-energy policies in a global context. Journal of Cleaner Production. In press.

Kaphengst, T., Ma, M. & Schlegel S. (2009). At a tipping point? How the debate on biofuel standards sparks innovative ideas for the general future of standardisation and certification schemes. In press.

Kashio, M. (1993). A Regional Overview of Eucalyptus Planting and the Scope of the Present Consultation - Based on the Presented Papers. In White, K., J. Ball and M. Kashio (Eds.). Proceedings Regional Expert Consultation on Eucalyptus 4-8 October. Volume 1. RAPA PUBLICATION 1995/6.

Kassam, A., Lutaladio, N., Friedrich, T., Kueneman, E., Salvatore, M., Bloise, M. & Tschirley, J. (2012). Natural Resource Assessment for Crop and Land Suitability: An application for selected bioenergy crops in Southern Africa region, Integrated Crop Management Vol.14-2012, AGP/FAO, Rome, 161 pp.

Keam, S. & McCormick, N. (2008). Implementing Sustainable Bioenergy Production. A Compilation of Tools and Approaches. Gland. IUCN: Switzerland.

Kimble, M., Pasdeloup, M. & Spencer, C. (2008). Sustainable Bioenergy Development in UEMOA Member Countries.

King J., Brown, C., Paxton, B. & February, R. (2004). Development of DRIFT, a scenario-based methodology for environmental flow assessments. Foundation for Water Research. Report Number 1159/1/04.

Kline K., Oladosu, G., Wolfe, A., Perlack, R., Dale, V. & McMahon, M. (2007). Biofuel Feedstock Assessment for Selected Countries. ORNL/TM-2007/224.

Knothe, G. (2005). Introduction. In The Biodiesel Handbook. Eds. Knothe, G., J. Gerpen and J. Krahl. Champaign, Illinois: AOCS Press.

Koga, N. (2008). An energy balance under a conventional crop rotation system in northern Japan: Perspectives on fuel ethanol production from sugar beet. Agriculture, Ecosystems and Environment 125 (1-4) 101–110.

Koh, L.P. & Wilcove, D. (2008). Is oil palm agriculture really destroying tropical biodiversity? Conservation Letters 1(2): 60-64.

Kojima, M. & Johnson, T. (2005). Potential for Biofuels for Transport

Kojima, M., Mitchell, D. & Ward, W. (2007). "Considering Trade Policies for Liquid Biofuels." Renewable Energy Special Report 004/07. ESMAP. Retrieved March 25, 2009, from http://siteresources.worldbank.org/INTOGMC/Resources/Considering_trade_policies_for_liquid_biofuels.pdf.

Koukios, E. & Diamantidis, N. (1998). Biomass for greenhouse gas emission REDuction (BRED) Agriculture as a source of biomass in Western Europe. Bioresource Technology Unit National Technical University of Athens Athens, Greece.

Kulay, L. & da Silva, G. (2005). Comparative Screening LCA of Agricultural Stages of Soy and Castor beans. Presentation held at 2ndInternational Conference on Life Cycle Management –LCM2005 in Barcelona, September 2-7.

Kulsum, A. & Sánchez Triana, E. (2008). SEA and Policy Formulation. In Kulsum, A. and E. Sánchez Triana (Eds.). Strategic Environmental Assessment for Policies. The World Bank.

Kusimi, J. (2008). Assessing land use and land cover change in the Wassa West District of Ghana using remote sensing. GeoJournal 71(4):249–259.

Kutas, G. (2008). Brazil's sugar and ethanol industry: endeless growth? Presentation at 11th European Sugar Conference. FO Lichts. Brussels, June.

Lam, M., Tan, M., Lee, K. & Mohamed, A. (2009). Malaysian palm oil: Surviving the food versus fuel dispute for a sustainable future. Renewable and Sustainable Energy Reviews 13(6-7): 1456-1464.

Lammers, E. (2009). Standardization and certification of sustainable biomass in the Netherlands SenterNovem. Presentation held at the international workshop Sustainability Certification for Biofuels and Bioenergy in Brussels, January 29-30.

Larson, E. (2006). A review of life-cycle analysis studies on liquid biofuel systems for the transport sector. Energy for Sustainable Development X(2): 109-126.

Leopold, A. (2010) TEEBcase: Agroecological Zoning, Brazil, available at: TEEBweb.org.

Lindblom, P. & Rasmussen, R. (2008). Bioenergy and Regional Development in the Nordic Countries. Nordregio Working Paper 2008:5. Retrieved August 12, 2009, from http://www.globalbioenergy.org/fileadmin/user_upload/gbep/docs/BIOENERGY_INFO/0806_Nordregio_-_Bioenergy_and_regional_development_in_the_Nordic_Countries.pdf.

Liska, A., Yang, H., Bremer, V., Klopfenstein, T., Walters, D., Erickson, G. & Cassman, K. (2009). Improvements in Energy Efficiency and Greenhouse Gas Emissions of Corn-Ethanol. Journal of Industrial Ecology 13(1): 58-74.

Lokko, Y., Okogbenin, E., Mba, C., Dixon, A., Raji, A & Fregene, M. (2007) Cassava. In Kole, C. (Ed.) Pulses, sugar and tuber crops. Heidelberg: Springer.

LowCVP. (Low Carbon Vehicle Partnership, 2009). http://www.lowcvp.org.uk/

Lucon, O., Viegas, R., de Azevedo, P. & Neto, F. (2008). São Paulo: sustainable ethanol. Secretaria de Estado do Meio Ambiente. Retrieved June 23, 2009, from http://homologa.ambiente.sp.gov.br/etanolverde/EV_GermanGovt_02mai08.pdf.

Luo, L., van der Voet, E. & Huppes, G. (2009). Life cycle assessment and life cycle costing of bioethanol from sugar cane in Brazil. Renewable and Sustainable Energy Reviews 13(6-7): 1613-1619.

Macedo, I. (2005). Socioeconomic impacts of the sugar cane agribusiness. In Macedo, I. (Ed.). Sugar Cane's Energy – Twelve studies on Brazilian sugar cane agribusiness and its sustainability. São Paulo Sugar Cane Agroindustry Union (UNICA): São Paulo.

Macedo, I. & Seabra, J. (2008). Mitigation of GHG emissions using sugar cane bioethanol. In "Sugar cane ethanol. Contributions to climate change mitigation and the environment". Zuurbier, P. and J. van de Vooren (Eds.). Wageningen: Wageningen Academic Publishers.

Macedo, I., Seabra, J. & Silva, J. (2008). Green house gases emissions in the production and use of ethanol from sugar cane in Brazil: The 2005/2006 averages and a prediction for 2020. Biomass and Bioenergy 32(7): 582-595.

Macedo I., Leal, M. & da Silva, J. (2004). Balanço das emissões de gases do efeito estufa na produção e no uso do etanol no Brasil. Secretaria do Meio Ambiente, Governo de São Paulo, April.

MagIndustries. (2009). Operations. Retrieved June 25, 2009, from http://www.magindustries.com/innerpage.aspx?pageid=41.

MAPA. (Brazilian Ministry of Agriculture, Livestock and Food Supply, 2006). Brazilian agroenergy plan 2006-2011. Retrieved June 24, 2009, from http://www.embrapa.br/english/publications/agroenery_miolo.pdf.

Marchettini, N., Niccolucci, V., Pulselli, F. & Tiezzi, E. (2007): Environmental Sustainability and the Integration of Different Methods for its Assessment. Env Sci Pollut Res 14 (4): 227–228.

Martin, B. (2003). Eucalyptus: A Strategic Forest Tree. In Wei, R. and D. Xu (Eds.). Eucalyptus Plantations. 3-19. World Scientific Publishing Co.: Singapore.

McKendry, P. (2002). Energy production from biomass (part 3): gasification technologies. Bioresource Technology 83(1):55-63.

Meissner, L. & Schukat, P. (2009). 'Testing Framework for Sustainable Biomass' Field Evaluation Analysis in Mozambique & Enabling Framework for Implementation. Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH.

Mekonnen, M.M. & Hoekstra, A. Y. (2011). "The green, blue and grey water footprint of crops and derived crop products", Hydrol. Earth Syst. Sci., 15, 1577–1600

Merrill, L. (2000).Glycine max. Retrieved June 23, 2009, from http://ecoport.org/ep?Plant=1150&entityType=PL****&entityDisplayCategory=full.

Ministry of Rural Development. (2005). Wastelands Atlas of India. New Delhi. Retrieved July 4, 2009, from http://dolr.nic.in/fwastecatg.htm.

Mitra S., Wassmann, R. & Vlek, P. (2005). An appraisal of global wetland area and its organic carbon stock. Current Science 88(1): 25-35.

Monnet, F. (2003). An Introduction to Anaerobic Digestion of Organic Wastes - Final Report. Retrieved August 4, 2009, from http://www.remade.org.uk/files/ctiontoAnaerobicDigestion_279515567.pdf.

Monteiro, C., Costa, M., Miyamaru, E. & Kulay, L. (2008). Environmental Comparison of Conventional and Organic Technological Routes for Sugar Obtaining Concerning to Greenhouse Gases Emissions. Presentation held at International Life Cycle Assessment & Management 2008 (InLCA/LCM 2008) – LCA VIII 'Calculating Consequences Beyond the Box' October 1 in Seattle. Retrieved August 14, 2009, from http://www.lcacenter.org/LCA8/session-biomass.html/.

Morel, A. (2007). How can biodiesel from jatropha be certified as sustainable and would India implement a certification scheme? Poster for Master Thesis. Environmental Change Institute Oxford University Centre for the Environment.

MPOB (Malaysian Palm Oil Board). 2007. http://www.mpob.gov.my/

MPOC (Malaysian Palm Oil Council). 2008. http://www.mpoc.org.my/

Nassar, A., Rudorff, B., Antoniazzi, L., Alves de Aguiar, D., Bacchi, M. & Adami, M. (2008). Prospects of the sugar cane expansion in Brazil: impacts on direct and indirect land use changes. In "Sugar cane ethanol. Contributions to climate change mitigation and the environment". Zuurbier, P. and J. van de Vooren (Eds.). Wageningen: Wageningen Academic Publishers.

Neilson, J. (2008). "Global private regulation and value-chain restructuring in Indonesian smallholder coffee systems," World Development 36, 1607-1622.

Neves do Amaral, W., Marinho, J., Tarasantchi, R., Beber, A & Giuliani, E. (2008). Environmental sustainability of sugar cane ethanol in Brazil. In "Sugar cane ethanol. Contributions to climate change mitigation and the environment". Zuurbier, P. and J. van de Vooren (Eds.). Wageningen: Wageningen Academic Publishers.

Nguyen, T., Gheewala, S. & Garivait, S. (2007). Energy balance and GHG-abatement cost of cassava utilization for fuel ethanol in Thailand. *Energy Policy* 35(9): 4585-4596.

Nielen, S. (2002). Brassica napus. Retrieved June 9, 2009, from http://ecoport.org/ep?Plant=549&entityType=PL****&entityDisplayCategory=full.

Norwana A., Kunjappan R., Chin M., Schoneveld G., Potter L. & Andriani R. (2011) "The local impacts of oil palm expansion in Malaysia An assessment based on a case study in Sabah State" Working Paper 78 CIFOR.

Nilsson, D. & Bernesson, S. (2008). Pelletering och brikettering av jordbruksråvaror - En systemstudie. Report 001. SLU Department of energy and technology.

Nitsch, M., & Giersdorf, J. (2005). „Biotreibstoffe in Brasilien." Volkswirtschaftliche Reihe Nr. 12. FU Berlin, Berlin.

Nivitchanyong. (2007). Biofuel Intitiatives in Thailand. National Science and Technology Development Agency, Thailand.

Nogueira, L. (2006). "Costos y precios para el etanol combustible en América Central (Convenio CEPAL/República de Italia)." LC/MEX/L.716. Naciones Unidas, Comisión Ecónomica para América Latina y el Caribe – Cepal, May 9.

Nordin, A., Simeh, M., Amiruddin, M., Weng, C. & Salam, B. (2004). Economic feasibility of organic palm oil production in Malaysia. Oil Palm Industry Economic Journal 4(2): 29-38.

Nouvellon Y., Epron, D., Kinana, A., Hamel, O., Mabiala, A., Annunzio, R., Deleporte, P., Saint-André, L., Marsden, C., Roupsard, O., Bouillet, J. & Laclau, J. (2008). Soil CO2 effluxes, soil carbon balance, and early tree growth following savannah afforestation in Congo: Comparison of two site preparation treatments. Forest ecology and management, 255 (5-6): 1926-1936.

Nussbaum, R., Garforth, M., Scrase, H. & Wenban-Smith, M.J. (2000). An analysis of current FSC accreditation, certification, and standard-setting procedures identifying elements which create constraints for small forest owners. Report for UK DFID Forestry Research Programme.

OAE. (Office of Agricultural Economics, 2003). Agricultural Statistics of Thailand Crop 2003/2004.
- (2008a). ECONOMIC ASSESSMENT OF BIOFUEL SUPPORT POLICIES. DIRECTORATE FOR TRADE AND AGRICULTURE.
- (2008b). Economic Assessment of Biofuel Support Policies. Summary of OECD Report Directorate for Trade and Agriculture. Press Conference, Paris, 16 July, 2008. Retrieved June 9, 2009, from http://www.oecd.org/dataoecd/54/10/40990370.pdf.

OECD-FAO. (Organisation for Economic Co-Operation and Development and Food and

Agriculture Organization of the United Nations, 2007). OECD-FAO Agricultural Outlook 2008-2017.
- (2009). OECD-FAO Agricultural Outlook 2009-2018. Highlights.
- (2010). OECD-FAO Agricultural Outlook 2010-2019. Chapter 4: Biofuels (pp 93-98).

Oladosu, K.D. (2009). Crop Land Use Change, Data and Modeling: Case Study of Brazil

Onvueme, I. (2002). Cassava in Asia and the Pacific. In Hillocks, R., J. Thresh and A. Bellotti. (Eds.). Cassava. Biology, Production and Utilization. CABI Publishing.

Orplana. (2007). Perfil dos produtores. Retrieved June 9, 2009, from http://www.orplana.com.br/perfil.html.

Pahl, G. & McKibben, P. (2008). Biodiesel: Growing a New Energy Economy. 2nd Ed. White River Junction: Chelsea Green Publishing.

Paiano et al. (2011). Implications and policies about the first generation biofuels: an international and EU analysis, New Medit, Issue: Vol 10, n.3, (September) pp. 56-64

Panichelli, L., Dauriat, A. & Gnansounou, E. (2008). Life cycle assessment of soybean-based biodiesel in Argentina for export. The International Journal of Life Cycle Assessment 14(2): 144-159.

Paturau, J. (1986). Alternative uses of sugar cane and its byproducts in agroindustries. In Sansoucy, R., G. Aarts and T. Preston (Eds.). Sugar cane as feed. La caña de azúcar como pienso. Proceedings of an FAO Expert Consultation held in Santo Domingo, Dominican Republic from 7–11 July 1986.

Pearce, D. & Mourato, S. (2006). Cost-benefit analysis and the environment. Organisation for Economic Co-operation and Development.

PEFC (Programme for the Endorsement of Forest Certification). 2009. http://www.pefc.org/

Peksa-Blanchard, M., Dolzan, P., Grassi, A., Heinimö, J., Junginger, M., Ranta, T. & Walter, A. (2007). Global Wood Pellets Markets and Industry: Policy Drivers, Market Status and Raw Material Potential. IEA Bioenergy Task 40.

Pelletier, N., Arsenault, N. & Tyedmers, P. (2008). Scenario Modeling Potential Eco-Efficiency Gains from a Transition to Organic Agriculture: Life Cycle Perspectives on Canadian Canola, Corn, Soy, and Wheat Production. Environmental Management 42(6): 989-1001.

Planeta Organico. (2004). Planeta Organico Visits. Retrieved June 25, 2009, from http://www.planetaorganico.com.br/enative1.htm.

Pleanjai, S. & Gheewala, S. (2009). Full chain energy analysis of biodiesel production from palm oil in Thailand. Applied Energy. In Press.

Preechajarn, S., Prasertsri, P. & Kunasirirat, M. (2008). Thailand Bio-Fuels Annual 2008. USDA Foreign Agricultural Service. GAIN Report TH8083

Prueksakorn, K. & Gheewala, S. (2008). Full Chain Energy Analysis of Biodiesel from Jatropha curcas L. in Thailand. Environmental Science & Technology 42 (9): 3388–3393.

Purchas, C. & Hutchinson, A. (2008). Consumer Information on Biofuel Sustainability, Options for Informing Consumers on Biofuel Sustainability. I:\AENVW\Projects\AE03364\Deliverables\AE03364W0006 Final.doc. Energy Efficiency and Conservation Authority, 25 February.

Purse, J. (2005). Eucalyptus species with biomass potential for the British Isles. Prima Bio. Retrieved June 29, 2009, from http://www.primabio.co.uk/bm_sppbiomasspotential.htm.

Rainforest Alliance. (2009). Sustainable Agriculture – Frequently Asked Questions. Retrieved August 11, 2009, from http://www.rainforest-alliance.org/agriculture.cfm?id=faq.

Rajagopal, D. 2007. Rethinking Current Strategies for Biofuel Production in India. Paper presented at the International Conference "Linkages between Energy and Water Management for Agriculture in Developing Countries", Hyderabad (India), January 29-30.

Rajagopal, D. & Zilberman, D. (2007). Review of Environmental, Economic and Policy Aspects of Biofuels. World Bank Policy Research Working Paper No. 4341, September 1.

Rajagopal, D., Sexton, S., Roland-Holst, D. & Zilberman, D. (2007). Challenge of biofuel: filling the tank without emptying the stomach? Environmental Research Letters 2(4): 1-9.

Rajkumar Abraham, E., Ramachandran, S. & Ramalingam, V. (2007). Biogas: Can It Be an Important Source of Energy? Environmental Science and Pollution Research 14 (1) 67 – 71.

Ratanawaraha, C., Senanarong, N. & Suriyapan, P. (2001). STATUS OF CASSAVA IN THAILAND: Implications for future Research and Development. In FAO (2001). A review of cassava in Asia with country case studies on Thailand and Viet Nam. Proceedings of the Validation Forum on the Global Cassava Development Strategy held in Rome, Italy. April 26-28, 2000. Volume 3.

Raunetsalo, J., Juslin, H., Hansen, E. & Forsyth, K. (2002). Forest Certification Update for the UNECE Region, Summer 2002. Geneva Timber and Forest Discussion Papers, ECE/TIM/DP/25. United Nations (UN).

Ray, R. & Bhardwaj, M. (2008). India sets new biofuel target, risks food price row. Reuters, September 11. Retrieved June 29, 2009, from http://uk.reuters.com/article/idUKDEL6739420080911?pageNumber=1&virtualBrandChannel=0.

REAP. (Resource Efficient Agricultural Production, 2009). Grass Biofuel Pellets. Retrieved April 23, 2009, from http://www.reap-canada.com/bio_and_climate_3_2.htm.

Reddy, B., Ramesh, S., Reddy, Ashok, A., Kumar, K., Sharma, S., Karuppan Chetty & Palaniswamy, A. (2007a). Sweet Sorghum Food, Feed, Fodder and Fuel Crop. Retrieved June 9, 2009, from http://www.icrisat.org/Biopower/dyetalSweetSorghumBrochureJan2007.pdf.

Reddy, B., Ramesh, S., Reddy, S., Ramaiah, B., Salimath, P. & Kachapur, R. (2007b). Sweet Sorghum – A Potential Alternate Raw Material for Bio-ethanol and Bioenergy. Retrieved June 9, 2009, from http://www.icrisat.cgiar.org/Biopower/ddySweetSorghumPotentialAlternative. pdf.

Reed, S. (2009). How Italy's ENI Vastly Boosted Oil Output. Businessweek April 9.

Reinhardt G., Gärtner, S., Rettenmaier, N., Münch, J., von Falkenstein, E. (2007). Screening Life Cycle Assessment of Jatropha Biodiesel. Final Report. IFEU - Insitute for Energy and Environmental Research Heidelberg GmbH.

REN21. (Renewable *Energy Policy* Network for the 21st Century, 2008). Renewables 2007 Global Status Report. REN21: Paris.

Rettenmaier, N., Köppen, S., Gärtner, S. & Reinhardt, G. (2008). Screening Life Cycle Assessment of Hydrotreated Jatropha Oil, Final Report. ifeu Institut für Energie- und Umweltforschung commissioned by Daimler AG, Stuttgart.

RFA. (Renewable Fuels Association) (2008). Ethanol Facts: Trade. Retrieved June 23, 2009, from http://www.ethanolrfa.org/resource/facts/trade/.
- (2009a). Ethanol Facts: Trade. Retrieved June 9, 2009, from http://www.ethanolrfa.org/resource/facts/trade/.
- (2009b). Annex C. In RFA. Carbon and Sustainability Reporting Within the Renewable Transport Fuel Obligation. Technical Guidance Part 1. Version 2.0 March 2009.

Rollefson, J., Fu, G. & Chan, A. (2004). Assessment of the Environmental Performance and Sustainability of Biodiesel in Canada. NRC CNRC. Prepared for: Ontario Ministry of Agriculture and Food Agriculture and Agri-Food Canada Environment Canada Industry Canada Natural Resources Canada.

Rosillo-Calle, F. & Walter, A. (2006). Global market for bioethanol: Historical trends and future prospects. Energy for Sustainable Development X(1): 18-30.

RSB. (Roundtable on Sustainable Biofuels 2008a). Background paper on labour and human rights. Retrieved June 23, 2009, from http://cgse.epfl.ch/webdav/site/cgse/shared/Biofuels/Working%20Groups/SOC%20WG/Backgrounders/Background%20paper%20%20labour%20rights%20SOC%20WG.pdf.

RSPO. (2011) "Promoting The Growth And Use Of Sustainable Palm Oil", RSPO (www.rspo.org)

RSPO. (Roundtable on Sustainable Palm Oil). www.rspo.org and http://www.rspo.eu/market/index.html

RTFO. (2011). RTFO Quarterly Report 12: 15 April 2010 – 14 April 2011, Renewable transport fuel obligation, UK (http://www.dft.gov.uk/statistics/series/biofuels/).

Rundgren, G. (2007). Building Trust in Organics - A Guide to Setting Up Organic Certification Programs. IOAS and IFOAM. Retrieved October 14, 2009, from http://www.ifoam.org/growing_organic/7_training/t_materials/4_quality_assurance/building_trust.php.

Sala, O., Sax, D. & Leslie, H. (2009). Biodiversity Consequences of Increased Biofuel Production. *In* Howarth, R. and S. Bringezu (eds). Biofuels: Environmental Consequences and Interactions with Changing Land Use. Proceedings of the Scientific Committee on Problems of the Environment (SCOPE) International Biofuels Project Rapid Assessment, 22-25 September 2008, Gummersbach, Germany.

Samutthong, N., Sarobol, E., Vichukit, V. & Thongpae, S. (2007). Effects of Amount and Rate of Watering on Cassava Growth and Yield Potential. Proceedings of the 45th Kasetsart University Annual Conference, Bangkok, Thailand, Jan. 30 – Feb. 2, 2007.

Saxena, R., Adhikari, D. & Goyal, H. (2007). Biomass-based energy fuel through biochemical routes: A review. Renewable and Sustainable Energy Reviews 13(1):167-178.

Schmidhuber, J. (2007). "Biofuels: An Emerging Threat to Europe's Food Security?Impact of an Increased biomass use on agricultural markets, prices and food security: A longer-term perspective." Policy paper 17/05/2007, Notre Europe, May.

Schut, Slingerland and Locke. (2010). Biofuel developments in Mozambique. Update and analysis of policy, potential and reality. *Energy Policy* 38(9), 5151-5165.

Scialabba, N. (2000). Factors influencing organic agricultural policies with a focus on developing countries. Paper presented at the IFOAM 2000 Scientific Conference in Basel, Switzerland, August 28-31. Food and Agriculture Organization of the United Nations (FAO).

Seabra, J. & Macedo, I. (2007). Energy balance and GHG emissions in the production of organic sugar and ethanol at São Francisco Sugar Mill. Retrieved August 14, 2009, from http://www.nativealimentos.com.br/eng/upload/CO2_Inventory.pdf.

Searchinger, T., Heimlich, R., Houghton, R., Dong, F., Elobeid, A., Fabiosa, J., Tokgoz, S., Hayes, D. & Yu, T. (2008). Use of U.S. Croplands for Biofuels Increases Greenhouse Gases Through Emissions from Land-Use Change. Science 319(5867): 1238 – 1240.

Serrano, R. (2002). Small farmers and organic agriculture in Argentina; general trends and the case of sugar cane growers in San Javier, Misiones. Office of Evaluation and Studies, IFAD, Rome.

Shapouri, Duffield & Wang. (2002). The Energy Balance of Corn Ethanol: An Update. U.S.

Department of Agriculture, Office of the Chief Economist, Office of *Energy Policy* and New Uses. Agricultural Economic Report No. 813.

Sheil, D., Casson, A., Meijaard, E., van Nordwijk, M., Gaskell, J., Sunderland-Groves, J., Wertz, K. & Kanninen, M. (2009). The impacts and opportunities of oil palm in Southeast Asia: What do we know and what do we need to know? Occasional paper no. 51. CIFOR, Bogor, Indonesia.

Sipos, B., Réczey, J., Somorai, Z., Kádár, Z., Dienes, D. & Réczey, K. (2009). Sweet Sorghum as Feedstock for Ethanol Production: Enzymatic Hydrolysis of Steam-Pretreated Bagasse. Applied Biochemistry and Biotechnology 153(1-3): 151-162.

Smeets, E., Junginger, M., Faaij, A., Walter, A., Dolzan, P. & Turkenburg, W. (2008). The sustainability of Brazilian ethanol—An assessment of the possibilities of certified production. Biomass and Bioenergy 32(8):781-813.

Smith, A. (2009). Sustainably Produced Bioethanol from Brazil. Presentation held at Sustainable Agriculture & Biofuels Certification Forum, World Biofuel Markets Congress, in Amsterdam, March 16.

Solidaridad. (2011). http://www.solidaridadnetwork.org/aboutus

Sparovek, Gerd, Göran, Egeskog, Berndes, A., Mazzaro de Freitas, F.L., Gustafsson, S. & Hansson, J. (2007). Sugar cane ethanol production in Brazil: an expansion model sensitive to socioeconomic and environmental concerns. Society of Chemical Industry and John Wiley & Sons, Ltd.

Sparovek, G, Barretto, A., Berndes, G., Martins, S.P. & Maule, R.F. (2009). Environmental,land-use and economic implications of Brazilian sugar cane expansion 1996-2006." Mitigation and Adaptation Strategies for Global Change 14.

Srinivasan A. (2000). Beta vulgaris var. saccarifera. Retrieved June 9, 2009, from http://ecoport.org/ep?Plant=48742&entityType=PL****&entityDisplayCategory=full.

Sriroth, K., Lamchaiyaphum, B. & Piyachomkwan, K. (2006). Present situation and future potential of cassava in Thailand. Cassava and Starch Technology Research Unit, Cassava Information Network. Retrieved April 28, 2009, from www.cassava.org/doc/presentsituation2.pdf.

Stattman, S., Bindraban, P. & Hospes, O. (2008). Exploring Biodiesel Production in Brazil. A study on configurational patterns in an evolving policy domain. Report 199. Wageningen: Plant Research International B.V.

Steenblik, R. (2007). "Biofuels at what cost? Government support for ethanol and biodiesel in selected OECD countries: A synthesis report addressing subsidies in biofuels in Australia, Canada, the European Union, Switzerland and the United States", Global Subsidies Initiative, IISD, September 2007.

Strezov, V., Evans, T. & Nelson, P. (2005). Cabonization of Biomass Fuels. In Brenes, M. (Ed.). Biomass and bioenergy. Nova: 91-124.

Subramaniam et al. (2008). Environmental Performance of the Milling Process Of Malaysian Palm Oil Using The Life Cycle Assessment Approach, American Journal of Environmental Sciences.

Sugandi, A. (2003). Characteristics of Peat and its Nutritional Requirements for Oil Palm Cultivation. Advanced Agriecological Research Sdn. Bhd. Newsletter March.

Sullivan, P. (2004). Sustainable Soil Management. Soil Systems Guide. National Center for Appropriate Technology (NCAT).

Sumathi, S., Chai, S., Mohamed, A. (2008). Utilization of oil palm as a source of renewable energy in Malaysia. Renewable and Sustainable Energy Reviews 12(9): 2404–2421.

Sustainable agriculture and soil conservation Soil-friendly farming systems and practices. © European Communities 2009; http://soco.jrc.ec.europa.eu/documents/ENFactSheet-06.pdf

Sustainable Biodiesel Alliance. (2009). Principles and Baseline Practices for Sustainability. Retrieved June 24, 2009, from http://www.sustainablebiodieselalliance.com/BPS%20V.1.pdf.

Sustainable production of biomass. (2006). Testing framework for sustainable biomass. Final report. Retrieved June 23, 2009, from http://www.senternovem.nl/mmfiles/CramerFinalReport_tcm24-280147.pdf.

Tan, K., Lee, K., Mohamed, A. & Bhatia, S. (2009). Palm oil: Addressing issues and towards sustainable development. Renewable and Sustainable Energy Reviews 13(2): 420-427.

TheBioenergySite News Desk. (2009). Germany Required to Revise Changes to Biofuel Law. February 2. Retrieved August 13, 2009, from http://www.thebioenergysite.com/news/2961/germany-required-to-revise-changes-to-biofuel-law.

The Royal Society. (2008). The Gallagher Review. The Renewable Fuels Agency.

Tomei, J. & Upham, P. (2009). Argentinean soy based biodiesel: an introduction to production and impacts. Energy Policy. In press.

Tonukari, N. (2004). Cassava and the future of starch. Electron. J. Biotechnol. 7(1): 5-8.

Trigueirinho, F. (2008). Soy Agribusiness and Sustainability. Presentation held at Environmental Parliamentary Front October 16. Retrieved June 24, 2009, from http://www.abiove.com.br/english/sustent/abiove_pal_sustenta_soja_out08_us.pdf.

Tungphaisal, M. (2002). Tapioca Products and Trade in Thailand. In Howeler, R. (Ed.) Cassava Research and Development in Asia: New Opportunities for an Ancient Crop. Proceedings of the 7th Regional Workshop held in Bangkok, Thailand, Oct. 28 - Nov. 1. The Nippon Foundation.

Turnbull, J. (1999). Eucalypt plantations. New Forests 17(1-3): 37–52.

Turner, B., Plevin, R., O'Hare, M. & Farrell, A. (2007). Creating Markets for Green Biofuels: Measuring and Improving Environmental Performance. Report commissioned by Natural Resources Defence Council (NRDC).

Uaiene, R. (2004). MAIZE AND SORGHUM TECHNOLOGIES AND THE EFFECTS OF MARKETING STRATEGIES ON FARMERS' INCOME IN MOZAMBIQUE. Master Thesis handed in at Purdue University December 2004. Retrieved June 9, 2009, from http://www.aec.msu.edu/fs2/mozambique/uaiene_ms.pdf.

UN. (United Nations, 1987). Report of the World Commission on Environment and Development, General Assembly Resolution 42/187, 11 December 1987.
- (2008). Making Certification Work for Sustainable Development: The Case of Biofuels. UNCTAD/DITC/TED/2008/1.

UNDP. (United Nations Development Programme, 2007). Malaysia Generating Renewable Energy from Palm Oil Wastes. UNDP Malaysia and the Global Environment Facility. Retrieved June 24, 2009, from http://www.energyandenvironment.undp.org/undp/index.cfm?module=Library&page=Document&DocumentID=6451.

UNDP. (United Nations Development Program, Energy & Environment, 2006). Environmental and Social Impact Assessment, Stora Enso Plantation Project in Guanxi, China. February 5. Retrieved August 12, 2009, from http://www.undp.org.cn/downloads/otherlocal/FinalESIA.pdf.

UN-Energy. (United Nations Energy, 2007). Sustainable Bioenergy: A Framework for Decision Makers. Retrieved May 5, 2009, from http://esa.un.org/un.energy/pdf/susdev.Biofuels.FAO.pdf.

UNEP. (United Nations Environment Programme, 2008). The Potential Impacts of Biofuels on Biodiversity, Matters arising from SBSTTA recommendation XII/7. Conference of the Parties to the Convention on Biological Diversity Ninth meeting Bonn, 19-30 May. UNEP/CBD/COP/9/26.

UNEP. (2009). Bioenergy: Managing risks and opportunities. An Overview of Key Issues under discussion and of UNEP's Bioenergy Programme
- (2009a). Quotes&Stats: Total Production.
- (2009b). Sugar cane Production – Brazil. Retrieved March 25, 2009, from http://english.unica.com.br/dadosCotacao/estatistica/.
- (2009c). The Industry - Production Map. Retrieved June 9, 2009, from http://english.unica.com.br/content/show.asp?cntCode={D6C39D36-69BA-458D-A95C815C87E4404D}.
- 2011, http://domesticfuel.com/2011/04/01/unica-expects-decline-in-brazil-ethanol-exports/

USDA. (United States Department of Agriculture, 2009a). USDA SUPPLY/DEMAND BALANCE SHEET FOR CORN. Retrieved June 9, 2009, from https://www.msu.edu/user/hilker/usdabscorn.htm
- (2009b). Feed Grains Database: Yearbook Tables. Retrieved June 9, 2009, from http://www.ers.usda.gov/Data/feedgrains/StandardReports/YBtable32.htm.

United States Department of Energy. (2009). Biobutanol Production. Alternative Fuels and Advanced Vehicles Data Center. Retrieved April 23, 2009, from http://www.afdc.energy.gov/afdc/fuels/emerging_biobutanol_production.html

United States Environmental Protection Agency. (1994). Emission Factor Documentation for AP-42 Section 9.9.7 Corn Wet Milling Final Report. EPA Contract No. 68-D2-0159. Work Assignment No. II-03. MRI Project No. 4602-03. Retrieved June 9, 2009, from http://www.epa.gov/ttn/chief/ap42/ch09/bgdocs/b9s09-7.pdf.

Valentin, C., Agus, F., Alamban, R., Boosaner, A., Bricquet, J., Chaplot, V., de Guzman, T., de Rouw, A., Janeau, J., Orange, D., Phachomphonh, K., Do Duy Phai, Podwojewski, P., Ribolzi, O., Silvera, N., Subagyono, K., Thiebaux, J., Tran Duc Toan & Vadari, T. (2008). Runoff and sediment losses from 27 upland catchments in Southeast Asia: Impact of rapid land use changes and conservation practices. Agriculture, Ecosystems & Environment 128(4): 225-238.

van Bueren, M. & Vincent, D. (2003). Eucalyptus biomass fuels: Price competitive or way off the money? Paper presented on the 47th Annual Conference of the Australian Agricultural and Resource Economics Society, in Perth, 12th-14th. Retrieved June 29, 2009, from http://www.aares.info/files/2003_vanbueren.pdf.

van Dam, J., Junginger, M., Faaij, A. I. Jürgens, G. Beste and U. Fritsche. (2008). Overview of recent developments in sustainable biomass certification. Biomass and Bioenergy 32(8): 749-780.

van Dam J. (2009). Greenhouse gas calculation methods, Workshop Sustainability certification for biofuels and bio-energy Brussels, Copernicus Institute - Utrecht University.

van Dam, J. A. Faaij, I. Lewandowski, B. Van Zeebroeck. (2009). Options of biofuel trade from Central and Eastern to Western European countries. Biomass and Bioenergy 33(4): 728-744.

van Dam, J., Faaij, A., Hilbert, J., Petruzzi, H. & Turkenburg, W. (2009a). Large-scale bioenergy production from soybeans and switchgrass in Argentina. Part A: Potential and economic feasibility for national and international markets. Renewable Sustainable Energy Review. In press.
- (2009b). Large-scale bioenergy production from soybeans and switchgrass in Argentina. Part B. Environmental and socio-economic

impacts on a regional level. Renewable Sustainable Energy Review. In press.

van Stappen, F. (2009). First implementations of sustainability schemes in European countries. Presentation held at the international workshop Sustainability Certification for Biofuels and Bioenergy in Brussels, January 29-30.

van Zon, L., Asselbergs, B., Wijnen, L., ten Velden, C., van der Noort, L. Harms, R. Vervuurt, R., van Hemert, J. & Bokhorst, J. (2006). Size does matter. The possibilities of cultivating Jatropha curcas for biofuel production in developing countries. Expertise Centrum voor Duurzame Ontwikkeling (ECDO), University of Amsterdam. Retrieved March 10, 2009, from http://environmental.scum.org/biofuel/jatropha/

Verified Sustainable Ethanol. (2009). http://www.sustainableethanolinitiative.com/default.asp?id=1062.

Vermeulen, S. & Goad, N. (2006). Towards better practice in smallholder palm oil production. iied. Retrieved June 23, 2009, from http://www.rspo.org/PDF/Projects/STF/final%20IIED%20report%20on%20smallholder%20palm%20oil.pdf.

Vis, M., Vos, J. & van den Berg, D. (2008). Sustainability Criteria & Certification. Systems for Biomass Production. Final report prepared for DG TREN – EUROPEAN COMISSION. BTG Biomass Technology Group BV.

von Braun, J. & Meinzen-Dick, R. (2009). "Land Grabbing" by Foreign Investors in Developing Countries, Risks and Opportunities. IFPRI Policy Brief No. 13, April.

Walter, A. & Piacente, E. (2007). "Ethanol Prices to Consumers: Trends and Perspectives in Brazil." Paper presented at the 15th European Biomass Conference, Mai 7-11. Berlin.

Walter, A. & Segerstedt, A. (2008). Biofuels – a chance for emerging and developing countries? In Dettling, D. (Ed.) Die Zukunft der Bioenergie – Herausforderungen und Perspektiven für die globale Nahrungs- und Energiesicherheit. Berlin: Berlinpolis.

Walter, A., Rosillo-Calle, F., Dolzan, P., Piacente, E. & Borges da Cunha, K. (2008a). Perspectives on fuel ethanol consumption and trade. Biomass and Bioenergy 32: 730-748.

Walter A., Dolzan, P., Quilodrán, O., Garcia, J., da Silva, C., Piacente, F & Segerstedt, A. (2008b). Brazilian Bio-ethanol: A Sustainability Analysis. Unicamp.

Watson H., Garland, G., Purchase, B., Dercas, N., Griffee, P. & Johnson, F. (2008). Bioenergy for Sustainable Development and Global Competitiveness: the case of Sugar Cane in Southern Africa. A compilation of Results from the Thematic Research Network: Cane Resources Network for Southern Africa (CARENSA). Thematic Report 1: Agriculture. Retrieved March 25, 2009, from http://www.carensa.net/tr/CARENSA-TR1-Agriculture_final.pdf.

Weyerhaeuser, H., Tennigkeit, T., Yufang, S., & Kahrl, F. (2007). Biofuels in China: An Analysis of the Opportunities and Challenges of Jatropha Curcas in Southwest China. ICRAF Working Paper Number 53. Retrieved July 05, 2009, from http://www.worldagroforestrycentre.org/sea/Publications/files/workingpaper/WP0088-07.PDF.

Wibawa, W., Mohamad, R., Omar, D. & Juraimi, A. (2007). Less hazardous alternative herbicides to control weeds in immature oil palm. Weed Biology and Management 7(4):242–247.

Willer, H., Yussefi-Menzler, M. & Sorensen, N. (Eds.) (2008). The World of Organic Agriculture. Statistics and Emerging Trends 2008. International Federation of Organic Agriculture Movements (IFOAM) Bonn, Germany and Research Institute of Organic Agriculture (FiBL), Frick, Switzerland.

Wolf, S. (2007). Bundesregierung – Entwurf der Biomassenachhaltigkeitsverordnung (BioNachV). Aktuelles aus Land und Bund. Sächsisches

Landesamt für Umwelt, Landwirtschaft und Geologie. Retrieved June 23, 2009, from http://www.biokraftstoff- portal.de/by/index.php?tpl=aktn&red=aktlistn&id=3301.

Wood, I. (2008). Palm oil round table 'a farce'. Telegraph November 28. Retrieved June 24, 2009, from http://www.telegraph.co.uk/earth/environment/forests/3534204/Palm-oil-round-table-a-farce.html.

Woods, J. (2003). Sorghum bicolor var. sweet. Retrieved June 9, 2009, from http://ecoport.org/ep?Plant=1982&entityType=PL****&entityDisplayCategory=full.

Woods, J. & Diaz-Chavez, R. (2007). OECD International Transport Forum. The Environmental Certification of Biofuels. Discussion Paper No. 2007-6.

World Rainforest Movement. (2001). Shell's eucalyptus plantations now provide even fewer jobs. WRM's bulletin Nº 46, May. Retrieved June 29, 2009, from http://www.wrm.org.uy/bulletin/46/Congo.html.

Worldwatch Institute. (2007). Biofuels for transport: global potential and implications for sustainable energy and agriculture. London: Earthscan.

WTO. (World Trade Organization, 2007). Biofuels, organic food proposed as environmental goods. WTO News Items, November 8. Retrieved August 10, 2009, from http://www.wto.org/english/news_e/news07_e/envir_nov07_e.htm.

WWF. 2010 Global Water Report – fast facts

WWF. Water Security Series 1 - Allocating Scarce Water - A primer on water allocation, water rights and water markets. April 2007 Tom Le Quesne, Guy Pegram and Constantin Von Der Heyden.

WWF review – September 2010; "Certification and Roundtables: do they work"?

Yee, K., Tan, K., Abdullah, A. & Lee, K. (2009). Life cycle assessment of palm biodiesel: Revealing facts and benefits for sustainability. Applied Energy 86(1): 189-196.

Zeng, X., Ma, ., & Ma, L. (2005). Utilization of straw in biomass energy in China. Renewable and Sustainable Energy Reviews 11(5): 976–987.

Zhao, Y., Dolat, A., Steinberger, Y., Wang, X. Osman, A. & Xie, G. (2009). Biomass yield and changes in chemical composition of sweet sorghum cultivars grown for biofuel. Field Crops Research 111(1-2): 55-64.

ANNEXES:

ANNEX 1: AGRONOMIC CONDITIONS FOR SELECTED FEEDSTOCKS

	Sugar cane	Sugar beet	Sweet sorghum	Maize	Wheat	Cassava
Optimal annual rainfall	1500	400	500	600	750	1000
Soil	moderate-high	moderate-high	low-moderate	low-high	moderate-high	low-moderate
Nutrients and agro-chemicals7	initially high nitrogen/potassium; afterwards low	high nitrogen and fertilizer needs	very high nitrogen, low fertilizer and pesticides	5 high fertilizer and pesticide input, high fertility	high	high nutrient absorption
Plant type	perennial	biennial	annual	annual	annual	perennial
Growing period	14-18 months	60-140 days	90-300 days	60-365 days	90-250 days	180-365 days
Climate	tropical	mainly temperate	tropical, sub-tropical, arid, semiarid	tropical, temperate	tropical, temperate	tropical, semiarid
Yields	Optimum: Average: 64 t/ha (Brazil)	6Optimum: 74 t/ha EU Average: 47.8t/ha	Stalk: 45-75t/ha Grain: 1.5-7.5 t/ha Global avarage grain: 1.3 t/ha	Optimum: 7-11 t/ha Average: 3.6 t/ha	Optimum: 6.3 t/ha	Optimum: 30 t/ha Small-holder: 5-15 t/ha
Labour intensity		medium				high7
Obtainable biofuel yield	26000 l/ha	45060 l/ha	4494 l/ha	23,500 l/ha	4 952 l/ha	4 2070 l/ha
Fruit period			-	-	-	

Notes: Biofuel yields are theoretical potential and are based on current average yields as well as main conversion assumptions except for oil palm and soy bean, which are based on national data for Malaysia and the US respectively. For further information, see sources: Ecocrop, 2009; 2 FAO The State of Food and Agriculture, 2008; 3 Tomei and Upham, 2009; 4 Rajagopal et al., 2007 5 EEA, 2006; 6 Ienica, 2007; 7 Kimble et al., 2008; 8 Cossalter and Pye-Smith, 2003;9 van Bueren and Vincent, 2003

	Country/source	LCA System Boundaries	Impact categories	Net energy gains (NEG)(MJ/liter) and fossil fuel balance(FFB)	Primary energy savings (Gj/yr/ha)	GHG reduction potential; other pollutants
Jatropha	India/LCA (Rettenmaier et al., 2008)	20 years depreciation period. All system input/ output but not production of processing equipment, vehicles Arable land is exluded.	Use of non-renewable energy GHG emissions (CO2, CH4, N2O) Pollutants (SO2, NOx, NH3, HCl, NOx, NH3, POCP) Ozone		Net petroleum offset: 13.4 per year and hectare	Advantageous when grown on areas with scarce vegetation but negative when considering medium vegetation
	Thailand Full chain energy analysis (Prueksakorn and Gheewala, 2008)	20 years depreciation period. All system input/ output but not production of processing equipment, vehicles Arable land is exluded.	Use of non-renewable energy GHG emissions (CO2, CH4, N2O) Pollutants (SO2, NOx, NH3, HCl, NOx, NH3, POCP) Ozone	FFB: 1.03-11.99 (0.53-2.70 excluding co-products)	Primary energy savings: 61.1-402.6 per year and hectare (incl. co-production)	Not considered
Maize	USA GHG Meta-analysis (EBAMM) (Farrell et al., 2006)	Energy inputs and outputs along the biofuel life-cycle. No land use change. CO-product credits included.	Use of non-renewable energy sources, GHG emissions (CO_2 equivalents)	NEG: 4.6 Net Energy ratio: 1.2		13% less GHG compared to petroleum
Maize	USA (nine major producing states) (De Oliveira et al., 2005)	Energy inputs and outputs along the biofuel life-cycle. No land use change and no co-products considered.	Use of non-renewable energy sources, GHG emissions (CO_2 and CH_4 and N_2O in CO_2 equivalents), ecological footprint; erosion rates; loss of biodiversity	FFB: 1.03-1.12		Ecological footprint: 1.74 for E85 and one automobile per year (compared with 1.11 for gasoline)

	Country/source	LCA System Boundaries	Impact categories	Net energy gains (NEG)(MJ/liter) and fossil fuel balance(FFB)	Primary energy savings (Gj/yr/ha)	GHG reduction potential; other pollutants
Sugar cane	Brazil, Sao Paolo (De Oliveira et al., 2005)	Energy inputs and outputs along the biofuel life-cycle. No land use change and no co-products considered. Electricity credits from bagasse.	Use of non-renewable energy sources, GHG emissions (CO_2 and CH_4 and N_2O in CO_2 equivalents), ecological footprint; erosion rates; loss of biodiversity	FFB: 3.14-3.87		Ecological footprint: 0.56 for ethanol and one automobile per year (compared with 0.56 for gasohol)
Sugar cane	Brazil (Luo et al., 2008)	10 years depreciation time. Energy inputs and outputs along the biofuel life-cycle. Electricity credits from bagasse.	Biotic depletion (ADP), GHG emissions, ozone depletion (ODP) photochemical oxidation (POCP), human toxicity (HTP & ETP), acidification (AP), eutrophication (EP)	n/a	n/a	83% less GHG compared gasoline; ADP is reduced by 81%, results for ethanol for ODP, POCP are better than gasoline but worse for HTP & ETP, AP and EP
Sugar cane	Centre-South Brazil (Macedo et al., 2008)	Energy inputs and outputs from seed-to-factory gate excluding fuel distribution and end-use stage. No land use change considered.	Use of non-renewable energy sources, GHG emissions (CO_2, N_2O, CH_4)	FFB: 6.7-11	n/a	85% for consumption in Brazil, 70% for consumption in Europe[1]
Cassava	Guangxi Province, China	Energy inputs and outputs for the whole life-cycle of ethanol Co-products only accounted for in cost-calculations No land use change considered.		NEG: 7.92 FFB:0.59		17% lower than gasoline

	Country/source	LCA System Boundaries	Impact categories	Net energy gains (NEG)(MJ/liter) and fossil fuel balance(FFB)	Primary energy savings (Gj/yr/ha)	GHG reduction potential; other pollutants
Cassava	Thailand (Nguyen et al., 2007)	Energy inputs and outputs for the whole life-cycle of the ethanol including energy equivalent for agricultural labour. No by-products considered.	Use of non-renewable energy sources, GHG emissions (CO_2, N_2O, CH_4)		720 Million liters per year	62.9% lower than gasoline. GHG abatement costs: US$99/t CO_2
Soy	China (Hu et al., 2008)	Energy inputs and outputs for the whole life-cycle. Co-product allocation based on product mass.	Use of non-renewable energy sources, GHG emissions (CO_2), hydrocarbons (HC), CO, particulate matter (PM), NO_x, SO_x	4% higher total energy consumption than gasoline		67% lower than conventional diesel; Lower life cycle HC, CO, PM and SO_x than fossil diesel but higher NO_x emissions
Soy	Argentina (Panichelli et al., 2008)	Energy inputs and outputs for the whole life-cycle (production in Argentina; consumption in Switzerland) Land use change only included for direct deforestation By-product allocation based on market values.	Use of non-renewable energy sources, GHG emissions (CO_2, NO_2, CO_2 equivalents), eutrophication (EP), acidification (AP), terrestrial ecotoxicity (TE), aquatic ecotoxicity (AE), human toxicity (HT), Land use competition (LU)		About 5 MJ-eq per km	About 20% higher than diesel; The biofuel performs worse than the fossil reference for all other categories.
Oil palm	Malaysia (Pastowski et al., 2007)	Energy inputs and outputs for the whole life-cycle, by-products included, implications of land use change assessed	Use of non-renewable energy sources, GHG emissions (CO_2, NO_2, and CH_4 in CO_2 equivalents)	n.a	130 GJ per hectare on both wasteland and peatland.	2.4-4.8t/yr/ha when replacing coal; 1.8 when replacing fossil diesel and -0.8 when replacing natural gas. GHG mitigation positive on tropical follow, negative on peatland

1 Results according to Walter et al. (2008b) where distribution stage has been added.

The global emergence of biofuels over the last two decades has been met with increased concerns over climate change and sustainable development. This report addresses the core issue of biofuel sustainability and related feedstocks, drawing from a wide range of studies, reports and policy initiatives. The report critically examines the economic, environmental and social sustainability dimensions of biofuels and reviews the major certification initiatives, schemes and regulations. The report draws on an extensive review of a number of country case studies covering a broad range of biofuel-feedstocks systems.

The analyses clearly distinguish feedstock efficiency (in terms of biofuel yields per unit of land) from sustainability, especially under limiting resources (irrigated water) or sensitive areas (carbon stocks). Long term economic viability depends on future policy support, technical innovations in biofuel systems, economics of biofuel supply and demand, and tradeoffs between food and energy uses as well as feedstock productivity gains. Biofuels can present both advantages and risks for environmental sustainability; the latter often being difficult to measure or monitor and may conflict with economic sustainability unless great strides in productivity gains are achieved. Social sustainability is the weakest link in current biofuel certification schemes owing to intrinsic local factors and the tendency to target only few negative social impacts. Much less focus is placed on inclusive processes that strengthen marginal stockholders participation and benefits.

Biofuel certification schemes need to be more smallholder inclusive, which require policy support. Finally, poor developing countries, especially with abundant land and biomass production potential, need to prioritize food security and poverty reduction. In many cases, biofuel models that encourage small scale integrated bioenergy systems may offer higher rural development impacts. FDI-induced larger-scale biofuel projects, on the other hand, may be suitable when specific conditions are met. This includes sufficient industrial capacity, land and biomass potential availability, and a strategy to integrate biofuel projects into domestic energy development programmes that do not conflict with food production potential and food security.

ISBN 978-92-5-107414-5

9 789251 074145

I3126E/1/11.12