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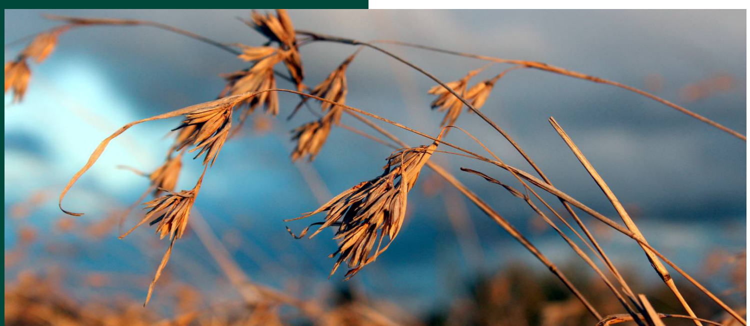
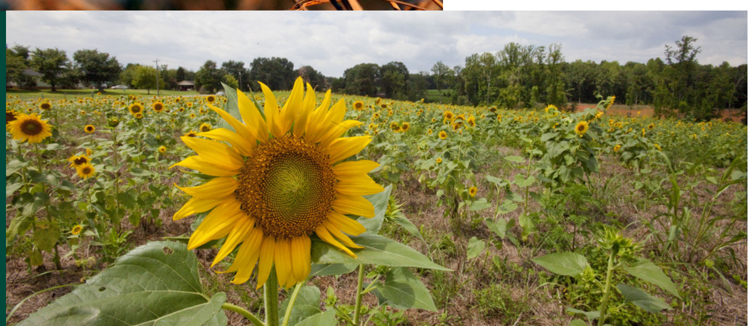
BIOFUELS AND BIODIVERSITY





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FOREWORD

Biofuels have been welcomed by many countries as part of global response for sustainable energy. However, there are concerns that their production and use could have significant impacts on biodiversity. Liquid transport fuels like ethanol and biodiesel have been heavily promoted in recent years as a means of increasing energy security, supporting agricultural producers, generating income and reducing greenhouse gas emissions. As many current biofuels are based on agricultural products, there are related concerns about the use of fertilizers, pesticides and water, as well as deforestation due to competing needs for land, an increasingly scarce resource.

At the ninth meeting of the Conference of the Parties to the Convention on Biological Diversity in 2008, work under the Convention on biofuels was integrated into the programme of work on agricultural biodiversity. Parties agreed that biofuel production and use should be sustainable in relation to biological diversity, and recognized the need to promote the positive and minimize the negative impacts of biofuel production and use on biodiversity and the livelihoods of indigenous and local communities.

In this report, the Secretariat has analysed and summarized some of the major issues related to biofuels and biodiversity on the basis of the best available scientific information. An earlier version of this study, prepared in response to decision X/37, was presented to the Convention's Subsidiary Body on Scientific, Technological and Technical Advice [1]. It is my hope that the current volume will help inform decision-makers and stakeholders across the many concerned sectors. The report highlights the complexities behind this topic. There are indeed opportunities for biofuels to contribute to sustainable development, but also risks. The challenge is to steer policies towards the first and away from the second. Throughout, the issues of scale, local specificities and realistic expectations must be at the forefront. It is necessary that decision-makers use the best available science to guide them towards more sustainable production and use of biofuels, and towards better agricultural practices in general.

Braulio Ferreira de Souza Dias
Executive Secretary
Convention on Biological Diversity

1 UNEP/CBD/SBSTTA/16/INF/32

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KEY MESSAGES / EXECUTIVE SUMMARY

- **The production of liquid biofuels has been rapidly increasing worldwide, mainly with a view to achieve greater energy security and to mitigate greenhouse gas emissions.** There are opportunities, but the energy security and greenhouse gas benefits of many current applications remain unproven. Although small-scale production of biofuels may be sustainable and have many beneficial applications, there have been concerns about the sustainability of large-scale production of biofuels, such as biodiversity loss, conflicts with food security and increased net greenhouse gas emissions.
- **Sustainability criteria and standards have been increasingly integrated into both voluntary certification schemes and national regulatory frameworks in order to provide more sustainable biofuels**. However, gaps in sustainability criteria and standards include leakage effects into the food and feed sector, and weak coverage of certain greenhouse gas, environmental and social impacts. Further development of criteria and standards is needed so that all possible relevant impacts are considered, based on full life-cycle analysis. There is much debate on whether or not biofuels should be regulated more stringently than other agricultural commodities, but most science supports approaches which improve the sustainability of agriculture at large, not by sub-sector.
- **Life-cycle analysis (LCA) is an accounting method widely used to assess and compare the carbon footprint of fuel types**. There are some limitations to LCA and there have been many suggestions to improve this tool. It is essential that LCAs of biofuels consider all impacts along the entire life-cycle and in particular land-use change. Further development and standardization of LCA could offer more comparable results between fuel types. LCA should include much more than greenhouse gas considerations; a broad range of assessment impact categories are necessary for a more holistic assessment of the ecological footprint of biofuels.
- **Land-use change resulting from increased biofuel production exacerbates the risk of losing biodiversity and ecosystem services and causing net increases in greenhouse gas emissions**. Different feedstocks and fuels, local variables and production practices have different energy input and output, and land use impacts. Advanced biofuels can offer some improvement over conventional biofuels provided they mitigate negative impacts, such as competing for land and water. While the areas devoted to biofuel production have increased, productive land is an increasingly scarce resource. The optimal use of land, water and other resources depends on a country's specific conditions and trade-offs among policy objectives. Improving the efficiency of feedstock production, conversion and use can help decrease pressure on land, water and other resources.
- **Indirect land-use change remains the key unresolved biodiversity-related issue, including for the assessment of life-cycle analysis for greenhouse gases.** There is inherent difficulty of addressing the cumulative impact of biofuels brought about through indirect land-use change caused through displacement effects. Because of the inherent uncertainties in the scale and severity of indirect land-use change, there have been few regulatory actions. Moreover, while ways and means to mitigate indirect impacts of biofuels are being advanced, they cannot fully eliminate them.
- **Focusing biofuel production on degraded or abandoned land may alleviate some land use pressures and may mitigate greenhouse gas emissions, but will probably not fill a high percentage of the world's energy demands.** Globally there is competition for degraded land for other uses, in particular food, but also forestry and urbanization. A major gap is the lack of an agreed definition, classification or quantification of "degraded" lands (and similar terminology). Life-cycle assessments for greenhouse gas emissions benefits also need to consider alternative uses of degraded land to capture and store carbon directly through ecosystem restoration.
- **The development of biofuels has been largely driven by Governments, primarily in developed countries, through mandates, targets, subsidies and various other incentives, including through trade policies.** These measures have come under considerable scrutiny as being insufficiently supported by science. These incentive measures usually fail to promote sustainability but there are significant opportunities to re-align them to deliver more positive outcomes. Financial support for biofuels that generate more environmental and greenhouse gas

emissions benefits should be prioritized, as well as incentives for research and development of biofuels that use wastes and residues as feedstock.

- **Biofuels feedstock expansion has occurred mostly in developing countries, where there are increasing concerns about food security of vulnerable populations.** The problem appears to lie mostly with large industrial-scale plantation and the process by which investors acquire land under customary use and ownership. Risks related to biofuels projects must be proactively managed to promote social and economic development in developing countries. Stakeholder participation, engagement in decision-making and monitoring progress are crucial to ensure that the local communities benefit from biofuels development, and for negative impacts to be prevented.
- **Biofuels need to be assessed more holistically under a broader framework of sustainable energy consumption and production.** There are many alternative renewable energy sources and the technology and economics of these are rapidly changing. Comparisons of biofuels with fossil fuels, using a full LCA approach, provide only part of the picture, which should be broadened to include comparisons with and amongst other renewable energy options. Biofuels may have a place in a sustainable energy portfolio – the issue is largely one of scale.
- **Sustainability of biofuels is a sub-set of, and depends on, achieving sustainability in all biomass-consuming and producing sectors.** At any significant scale, biofuels cannot be considered sustainable unless the other uses of resources they rely on become sustainable in parallel. The key need is for effective strategic planning tools and approaches to address sustainable consumption and production under multiple resource pressures, and a policy mechanism responsive to them. Increased synergy and coordination between biofuels, ecosystem-based climate change mitigation options and integrated land-use planning can better address the needs of all sectors, biodiversity, ecosystem services and people.

INTRODUCTION

Biofuels powered cars before fossil fuels became the dominant fuel; Henry Ford designed his original 1908 Model T to run on ethanol, and Rudolph Diesel intended to power his engine with vegetable oil (Schubert 2006; English 2008). Henry Ford predicted in 1925, "*The fuel of the future is going to come from fruit like that sumac out by the road, or from apples, weeds, sawdust - almost anything. There is fuel in every bit of vegetable matter that can be fermented*[2]". Due to their supply, price and efficiency (and also due to prohibition), fossil fuels became more practical, and the use of biofuels dissipated (Schubert 2006; English 2008). Biofuels have been embraced decades later as a potentially attractive option to resolve some of the greatest challenges of today: dwindling fossil fuel supplies, high oil prices and climate change. Biofuels have the potential to stimulate economic development, especially in rural areas of developing countries and can provide cheap, renewable, locally sourced, carbon neutral fuel (IEA 2011; Nuffield Council on Bioethics 2011; UNEP 2012a). Biofuels and other renewable energy sources are now back on the political agenda, and there is much talk and activity about biofuels from many players in many sectors.

Any discussion of the topic of biofuels is compounded by the considerable diversity of energy sources, production methods and scale. Technologies range from millennia-old traditional bio-energy (e.g., using livestock dung for heating) to modern technologies (e.g., dedicated bioenergy crops to produce liquid fuels to replace petroleum-based sources in transport). The topic therefore requires perspective. Prior to the very recent advent of fossil fuels as the dominant energy source – bioenergy sources were the norm, and in particular unsustainable use of forest timber and whale oil. Even among modern technologies there are diverse applications where impacts vary considerably according to locally specific conditions. The information landscape is populated by examples which can be used to defend or attack biofuels. This is one subject where unsubstantiated generalizations are widespread, exceptions easily found and where there is a conspicuous role for better science.

The current report discusses biofuels largely as the term is popularly used today; that is, the production of significant amounts of bio-energy derived fuels largely as perceived as an alternative to petroleum based sources. There is, therefore, already an element of scale to the topic. Beeswax candles at the local craft market are no less a biofuel than ethanol at the nearby gas station – but it is the latter where scale determines relevance.

So far, modern biofuels that are in commercial production today, or "first generation" ethanol and biodiesel from food crops, have not come close to replacing fossil fuels, as biofuels represent about 2% of total transport fuels used globally today (IEA 2011). This is mostly due to the constraints in land and water to grow biomass for biofuels, as well as the lack of cost-competitive and efficient technologies to produce biofuels (Giampetro *et al*. 1997; Schubert 2006). Ligno-cellulosic "second generation" biofuels produced from the woody part of the plant such as wheat straw, corn husks, trees or prairie grass, and especially those produced from waste and surplus biomass from existing agricultural or forestry systems are a potentially more abundant energy source than food crops (Schubert 2006; Sanderson 2011). The production of biofuels from ligno-cellulose instead of food crops could help reduce competition with food production and the need for land and resources, which are rapidly being depleted by competing uses (Nuffield Council on Bioethics 2011). However, the processing of ligno-cellulose is currently expensive and is restricted by technological limitations, although there has been much research to overcome these constraints (Schubert 2006; Sanderson 2011). Algae are another option that could be 200 times more productive per hectare than a land-based crop, and reduce pressures on land use (although they may shift these pressures to other ecosystems such as wetlands) (Schubert 2006; Nigam and Singh 2011). Advances in synthetic biology have increased interest in this avenue and there has been progress producing larger quantities of algal biofuels and reducing production costs (see review by Dixon 2012).

Biofuels can offer some benefits over fossil fuels but there are concerns with regard to biodiversity conservation and sustainable use. Although small-scale production of biofuels may be sustainable and have many beneficial applications, there have been concerns about the sustainability of large-scale production of biofuels. Biofuels in commercial production today often involve significant biodiversity loss through destruction of natural habitats

2 *Ford Predicts Fuel from Vegetation,* N.Y. TIMES, Sept. 20, 1925, at 24.

and pollution, and can be in direct conflict with food security (see Nuffield Council on Bioethics 2011). Biofuels have the potential to affect all of the major drivers of biodiversity loss identified in Global Biodiversity Outlook 3 (SCBD 2010): habitat loss and degradation; climate change; excessive nutrient load and other forms of pollution; over-exploitation and unsustainable use; and invasive alien species. Furthermore, although biofuels are partly intended to mitigate climate change by reducing greenhouse gas (GHG) emissions, many biofuels used today emit as much, or more, GHGs as fossil fuels or offer very limited savings, when taking into account their entire lifecycle, and when indirect land-use change is taken into consideration (e.g., Fargione *et al.* 2008; Searchinger *et al*. 2008). The impact of biofuel production on biodiversity will depend on the feedstock used, management practices, land-use changes and energy processes (UNEP/GRID Arendal 2011). Biodiversity can also be better protected through sustainable agriculture, reducing agricultural inputs and restoring degraded lands (UNEP/GRID Arendal 2011).

Purpose, structure and scope of this report:

As detailed in Box 1, the Convention on Biological Diversity (CBD) has a mandate in the field and has agreed that biofuel production and use should be sustainable in relation to biological diversity with actions seeking to "promote the positive and minimize the negative impacts of biofuel production and its use on biodiversity and the livelihoods of indigenous and local communities". The Conference of the Parties requested that the CBD Secretariat examine tools and approaches as well as gaps pertaining to the sustainable production of biofuels. Because transportation is a sector that contributes significantly to GHG emissions, the present report focuses on liquid biofuels used in transportation.

The purpose of this report is to inform Parties, decision-makers, scientists and the general public on the complex relationship between biofuel production and use, and the conservation and sustainable use of biodiversity, as well as tools and approaches available to address sustainability, and remaining gaps in this regard. This report builds upon an information note[3] that was prepared for the consideration of the sixteenth meeting of the Subsidiary Body on Scientific, Technical and Technological Advice (SBSTTA) to the CBD in response to decision X/37[4]. This information note provides the primary source of information for this report and further details the work undertaken, including the analysis of information submitted by Parties[5] and collected from recent scientific literature.

The scope of this report, consistent with that of the CBD, is "biodiversity". Because of the complex inter-relationships between biofuels and biodiversity the boundaries of the topic can be difficult to define. Few aspects of biofuel production and use, and associated policies, are independent of potential impacts on biodiversity. Below is a short overview of each section of the report:

- Section 1 of this report reviews how biofuels are produced: depending on the type of crop/biomass used, location, scale and national circumstances, biofuels can have very different energy security benefits and impacts on people and the environment. Recent technological advances offer some solutions to the shortcomings of the first generation of biofuels made from food crops.
- Section 2 examines government regulations, sustainability criteria and certification schemes, and how these influence the impacts of biofuels on biodiversity. A number of countries and regions have introduced policies or adopted standards that promote more sustainable practices for biofuel production and use. Biofuels producers may also receive certification by abiding by the principles and standards from voluntary initiatives.
- Section 3 considers biofuels as one amongst many renewable energy options and how comparisons should be made amongst those options with regards to sustainability and impacts on biodiversity.

3 UNEP/CBD/SBSTTA/16/INF/32: Biofuels and Biodiversity: Further Information on the Work in Response to Decision X/37, available at: http://www.cbd.int/doc/meetings/sbstta/sbstta-16/information/sbstta-16-inf-32-en.pdf

4 Full decision text available here: http://www.cbd.int/decision/cop/?id=12303

5 In response to notification 2011-121; submissions are available at http://www.cbd.int/agro/biofuels/responses.shtml

- Section 4 focuses on life-cycle analysis, which is a commonly accounting method to assess the carbon footprint of various types of fuels. This information helps determine which fuels have the lowest emissions compared to fossil fuels. This is highly relevant to biodiversity as climate change is one of the major drivers of biodiversity loss and much of the carbon emissions from land use derive from biodiversity loss (e.g., loss of carbon stored in soils and forests).
- Section 5 examines how land-use change from biofuel production exacerbates the risk of losing biodiversity and ecosystem services. Other concerns linked to land-use change include significant greenhouse gas emissions, especially when conversion of agricultural lands to biofuel production has led to deforestation.
- Section 6 reviews biofuels targets, subsidies, tariffs and other economic measures. Expansion of biofuel production is largely driven by government intervention. It is important for public policy—and the associated incentive structure—to be developed in such a way that this expansion not only contributes to mitigating greenhouse-gas emissions but is also consistent with the conservation and sustainable use of biodiversity.
- Socio-economic impacts of biofuels, addressed in Section 7, include interactions between biofuels and food security, which are indeed complex, but at least part of the issue pertains to the conservation and sustainable use of biodiversity. In less economically advanced communities, increasing food prices or shifts in local crops from food to energy, will increase pressures on local biodiversity resources (e.g., bushmeat). Biofuel production can impact local ecosystem services and therefore also their ability to support local food security. In addition to rights issues, the alienation of local communities from land carries with it significant implications for biodiversity through the loss of associated traditional knowledge associated with biodiversity on that land and therefore potentially undermines its sustainable use.
- Section 8 concludes that the primary need regarding sustainable biofuel production and use, with regards to biodiversity, concerns the broader issue of sustainable consumption and production under multiple pressures. This includes better land use planning on an international and regional level across all agricultural commodities and biomass consuming and producing sectors.

BOX 1: Biofuels and the Convention on Biological Diversity (CBD)

In decision IX/1, the Conference of the Parties to the CBD decided to integrate the issue of biofuel production and use into the programme of work on agricultural biodiversity. In decision IX/5 on forest biodiversity, Parties, other Governments, and relevant international and other organizations were invited to address both, direct and indirect, positive and negative impacts that the production and use of biomass for energy, in particular large-scale and/or industrial production and use, might have on forest biodiversity and on indigenous and local communities, also taking into account the components of the decision IX/2 on biofuels and biodiversity relevant to forest biodiversity, reflecting varying conditions of countries and regions.

The Conference of the Parties also agreed in decision IX/2 that biofuel production and use should be sustainable in relation to biological diversity. The Conference of the Parties recognized the need to promote the positive and minimize the negative impacts of biofuel production and its use on biodiversity and the livelihoods of indigenous and local communities and agreed on activities for doing so including:

- The development and application of sound policy frameworks for the sustainable production and use of biofuels;
- Research and monitoring of the positive and negative impacts of the production and use of biofuels on biodiversity and related socio-economic aspects, including those related to indigenous and local communities;
- Strengthened development cooperation with a view to promote the sustainable production and use of biofuels;
- Encouraging the private sector to improve social and environmental performance of the production of biofuels.

In decision X/37, the Conference of the Parties recognized the need for the continuing improvement of policy guidance and decision making to promote the positive and minimize or avoid the negative impacts of biofuels on biodiversity, and impacts on biodiversity that affect related socioeconomic conditions. For this purpose, Parties, other Governments and relevant organizations are encouraged to:

- Address gaps in scientific knowledge;
- Improve scientific, environmental and socio-economic research and assessments;
- Conduct open and transparent consultation, with the full and effective participation of the concerned indigenous and local communities; and
- Share best practices.

In paragraph 12 of decision X/37, the Conference of the Parties requested the Executive Secretary to compile information on gaps in available standards and methodologies, identified in the work undertaken in paragraph 11[6] of that decision, and bring it to the attention of relevant organizations and processes. The Executive Secretary was requested to report on progress in these regards to a meeting of the Subsidiary Body on Scientific, Technical, and Technological Advice (SBSTTA) prior to the eleventh meeting of the Conference of the Parties.

Accordingly, the Executive Secretary prepared a note for the consideration of the sixteenth meeting of the Subsidiary Body. This information note provides the primary source for this report and further details the work undertaken, including the analysis of information submitted by parties (re. notification 2011-121; available at http://www.cbd.int/agro/biofuels/responses.shtml) and collected from recent scientific literature.

6 In summary, paragraph 11 of decision X/37 requested the Executive Secretary, subject to the availability of financial resources, to compile, assess and summarize information on tools for voluntary use to assess direct and indirect effects and impacts on biodiversity of the production and use of biofuels, in their full life cycle as compared to that of other types of fuels, and impacts on biodiversity that affect related socio-economic conditions, taking into account the work of, and in collaboration with, relevant partner organizations and processes, building on relevant decisions taken and guidance developed by the Convention on Biological Diversity.

1. HOW BIOFUELS ARE PRODUCED

Biofuels are solid, liquid or gaseous fuels that are produced from biomass (Giampietro *et al*. 1997; IEA 2011). The biomass or organic matter that is converted to biofuels may include food crops, dedicated bioenergy crops (e.g., switchgrass or prairie perennials), agricultural residues, wood/forestry waste and by-products, animal manure and algae (Giampietro *et al*. 1997; IEA 2011). A biofuel feedstock is defined as the raw material or biomass used to manufacture the biofuel. The primary liquid biofuels used in the transport industry on a commercial scale today are ethanol, made from the fermentation of sugary/starchy crops such as sugar cane and corn, and biodiesel, which can be obtained from oil crops such as oil palm and soybeans (IEA 2011). Both ethanol and biodiesel can be blended with conventional gasoline and diesel and used as liquid fuels in conventional engines for transportation. Biogas is also a commonly used biofuel that is made from the anaerobic fermentation of biomass and used for cooking, heating, and can be used in natural gas vehicles. Conventional biofuels or "first generation biofuels" are well established and used on a commercial scale, while advanced biofuels, or "second/third generation" biofuels, are still in the research and development, pilot or demonstration phase. Advanced biofuels include ligno-cellulosic biofuels, algae-based biofuels, biodiesel, and bio-synthetic gas. Feedstocks typically used for advanced biofuels include woody biomass, grasses, agricultural by-products, algae and seaweed (IEA 2011). Figure 1.1 illustrates the major groups of biofuels and feedstocks used or under development today.

KEY DEFINITIONS (FAO, 2004)**:**

Biofuels**:** "Fuel(s) produced directly or indirectly from biomass"

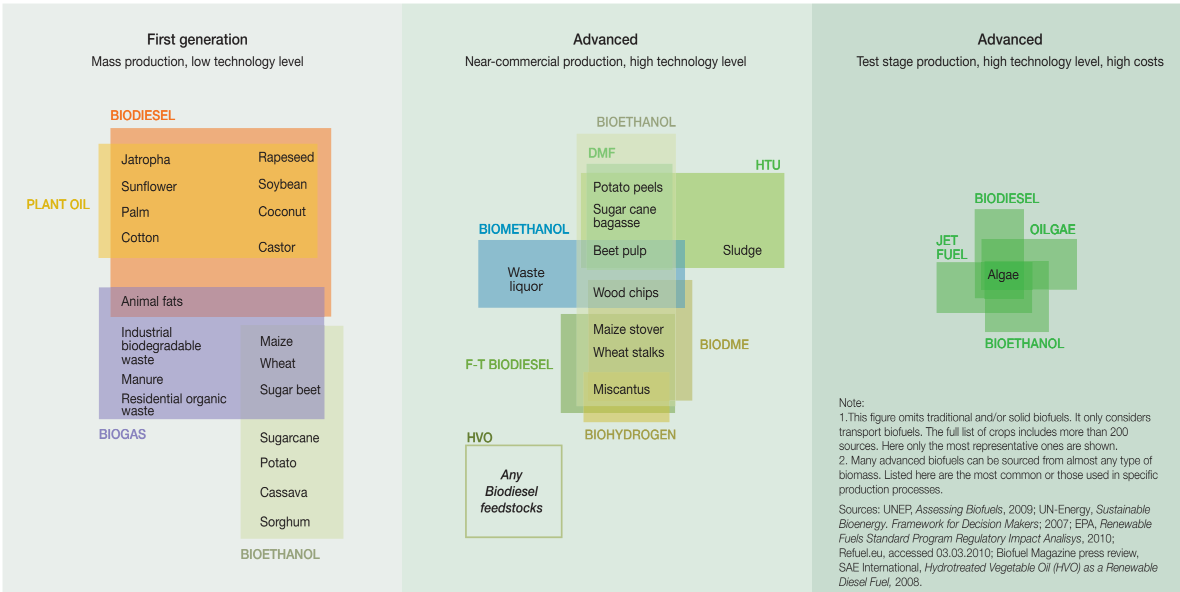
Biomass**:** "Material of biological origin excluding material embedded in geological formations and transformed to fossil"

Bioenergy: "All energy derived from biofuels"

In recent years, the production of liquid biofuels has been increasing worldwide, mainly spurred by efforts for greater energy security and to mitigate greenhouse gas (GHG) emissions. While biofuel production has never really been significant at a global scale due to the low price of oil, the role of biomass as a fossil fuel energy substitute has regained a great deal of interest in the past decade due to: (i) instability in petroleum-producing countries; (ii) the rising cost of petroleum in the past decade, and (iii) the adoption and entry into force of the Kyoto Protocol[7], which requires ratifying countries to reduce GHG emissions. Derived from renewable sources, biofuels have the potential to be more or less carbon-neutral, since in theory the carbon released during their combustion can be taken up by growing the plants used as feedstock (but see Section 4: Life-cycle analysis). Liquid biofuels have been reported to release less GHG than conventional fossil fuels (Perlack *et al.* 1992; Huston and Marland, 2003; Kim and Dale 2005; WI and GTZ 2006). However in some cases, conventional biofuels may deliver limited reductions, and even net increases, in greenhouse gas (GHG) emissions (e.g., Fargione *et al.* 2008; Searchinger *et al.* 2008). As a substitute for oil, biofuel is also considered a practical solution because it keeps the premium value of liquid fuels for which a distribution infrastructure is already available (e.g. gas stations) and no significant modification of existing vehicles is needed if gasoline or diesel is mixed with biofuel (WI and GTZ 2006). Therefore, biofuel production can bring countries energy security, protect them from energy-pricing risks over which some countries have little control, and result in significant savings in foreign exchange, which can instead be invested in the domestic economy.

7 http://unfccc.int/kyoto_protocol/items/2830.php

Figure 1.1: The enlarged biofuels family



Credit: Riccardo Pravettoni, UNEP/GRID Arendal (http://www.grida.no/graphicslib/tag/biofuels)

Although small-scale production of biofuels may be sustainable and have many beneficial applications, there have been concerns about the sustainability of large-scale production of biofuels. The scale of the biofuel industry and the number of countries involved in its production and use are expanding at an accelerated pace (WI and GTZ, 2006). Global biofuel production has grown from 16 billion litres in 2000 to more than 100 billion litres (volumetric) in 2010 (IEA 2011). The biofuel market is now worth more than US$80 billion a year and received over US$ 22 billion in subsidies in 2010, which are projected to further increase (GSI 2012). There is growing concern that replacing an increasing portion of fossil fuels with biofuels will accelerate agricultural expansion. Conventional biofuels typically use large tracts of land that would normally have been dedicated for agricultural production, and can cause deforestation through direct or indirect land use change (see Section 5: Land use). For example, in Indonesia and Malaysia, extensive areas of tropical rainforests, including in protected areas, have been cleared for oil palm plantations (Hensen 2005; Dennis and Colfer 2006). Yet, there are exceptions and these invariably involve strong government commitment backed by effective programmes to move production towards sustainability (sugarcane in Brazil being the most widely quoted example). Biofuel production is constrained by the availability of land and fresh water, and its intensive production can degrade land, cause water and air pollution, and biodiversity loss (Giampietro *et al.* 1997; Groom *et al.* 2008). For example, corn biofuels, the most widely used biofuel in the United States of America (USA), require some of the highest fertilizer and pesticide inputs per acre with detrimental effects on biodiversity.

Advanced biofuels can offer some improvement over conventional biofuels provided they mitigate negative impacts, such as competing for land and water (Nuffield Council for Bioethics 2011). Many types of biofuels show promise but most require more research and development before they can be commercialized. An area of biofuel research which has advanced rapidly has been ligno-cellulose technology, which uses non-food crops or waste cellulose from forestry and farming systems (Schubert 2006; Sanderson 2011). Ligno-cellulosic biofuels are derived from grasses, crop and wood residues, and fast growing trees, using all parts of the plant, rather than solely the sugary, starchy or oily parts. In efforts to reduce agricultural impacts, and prevent conversion of natural habitats and threats to food security, there has been increased enthusiasm for integrating bioenergy production from "waste" products or "surplus" biomass (Schubert 2006; Sanderson 2011). Using the non-food components of food crops (usually "waste" cellulose) for bioenergy is a way to integrate energy and food production (UNEP 2009a; Sanderson 2011). Bioenergy production from wastes is especially effective when it is integrated into

BOX 1.1: Historical perspectives on biofuels

Biofuels are not a recent discovery. Solid biofuels, such as wood, charcoal and dried manure, have been used ever since man discovered fire (Songstad *et al.* 2009). Liquid biofuels derived from plants and animals, such as whale oil and olive oil, have been used as lamp oil since at least early antiquity. The internal combustion engine, invented by Samuel Morey (US Patent 4378 Issued April 1, 1826), was designed to run on a blend of ethanol and turpentine (derived from pine trees) (Songstad *et al.* 2009). Biofuels were the primary energy source until coal became available on a large scale in the developed world in the late 19th century (Fernandes *et al*. 2007). In the developing world, solid biofuels continue to be used as an important source of heat and cooking fuel (Fernandes *et al.* 2007).

Petroleum or crude oil has also been used since ancient times in various forms; however, the first commercial oil well has been attributed to Edwin Drake in 1859 near Titusville, Pennsylvania, USA (although others existed around the same time in other parts of the world) (Kovarik 1998). Also developed and commercialized in the mid-19th century was kerosene, which became the first combustible hydrocarbon liquid (Kovarik 1998). Prior to the development of kerosene, the energy crisis was centred on finding a replacement for diminishing supplies of whale oil, which was heavily used in the mid 1700s and early 1800s (Dolin 2007; Songstad *et al.* 2009). The whaling industry declined in the mid-to-late 19th century due to the widespread availability of cheaper kerosene (Schneider and Pierce 2004; Songstad *et al.* 2009).

During World War I, it was recognized that ethanol could be blended with gasoline to produce a suitable motor fuel. The scientific consensus at the time was that ethanol would be an essential component of motor fuels of the future (Kovarik 1998). Ethanol was in high demand in World Wars I (1917–1919) and II (1941–1945), due to oil shortages and to limit oil imports (Songstad *et al.* 2009).

In more recent times there have been several oil crises since the 1970s:

- 1973 oil crisis: caused by the Organization of Arab Petroleum Exporting Countries (OAPEC) oil export embargo.
- 1979 oil crisis: caused by the Iranian Revolution.
- 1990 oil price shock: caused by the Gulf War.

These crises lead many countries, including Brazil and the USA, to begin the modern large-scale production of biofuels (Fernandez et al. 2007).

existing agricultural and forestry systems and biomass refining and processing (UNEP 2009a). The development of bio-refineries can increase resource efficiency by producing solid residues that can provide the bio-refinery with "free" power, and produce chemicals or other fuels (Fairley 2011; UNEP/GRID Arendal 2011).

The use of waste cellulose as a biofuel feedstock could help reduce competition for land and resources; however, its availability in farming and forestry systems is debated. Much of the waste cellulose available is actually required to support soil functions and fertility and often directly supports biodiversity. Examples of potential waste feedstock from agricultural systems include corn stover and straw from food crops such as wheat and rice. Some suggest (e.g., Tilman *et al.* 2009) that conservative removal rates could provide a sustainable feedstock source. However other researchers (e.g., Lal 2006) argue that the crop residues need to be increasingly used to maintain soil fertility and reduce erosion, and are important in conservation tillage practices aimed at increasing the sustainability of agricultural practices. Wood and forest residues, including branches from harvesting operations, forest thinnings, and residues from mill and pulp operations can also provide a source of feedstock (Tilman *et al.* 2009). However, this approach is not without constraints. For example, the Finnish Environmental Agency modelled the carbon impact of increased forest biomass use and found that using more wood for bioenergy is leading to decreasing carbon stocks in the Finnish forests (Liski *et al.* 2011). This is because soil carbon levels are lower and burning wood releases carbon more quickly than leaving dead wood to decay slowly; both transport and chipping of wood cause emissions; and different parts of a tree have different GHG reductions benefits. Furthermore, dead wood provides habitat for a great diversity of species important for forest ecosystem function, and a large proportion of fallen and standing dead wood should be left for wildlife (Jonsson *et al.* 2005).

Dedicated ligno-cellulosic feedstocks such as trees and grasses (e.g., willow, poplar, switchgrass, perennial grasses, short rotation trees) could also offer some advantages for biofuel production. These offer some potential provided that they require low water, fertiliser and pesticide inputs and that they are grown on "unused" or degraded land (see Section 5.1: Growing biofuels on degraded lands) (Tilman *et al.* 2006). Ligno-cellulosic biofuels are often regarded as a means to minimize direct and indirect land-use change (because productivity gains reduce overall land pressures from biofuels) but further science on their use suggests that this is very much case specific. Some studies have suggested that ligno-cellulose derived biofuels may require a larger land area (on a global scale) than first generation biofuels (Gallagher 2008; Gurgel *et al.* 2008; Rubin 2008; FAO 2008a). On the other hand, others propose that cultivating a larger area under polyculture or semi-natural habitat with low inputs, rather than a smaller area of land under monoculture with high inputs, could be more beneficial to biodiversity while decreasing pest and soil fertility problems (Tilman *et al.* 2006; Groom *et al.* 2008). High energy yields have been obtained per hectare using a diversity of native grasses under this low input semi-natural approach by Tilman *et al.* (2006), with a carbon neutral to carbon negative GHG balance (See Box 1.2, below).

BOX 1.2: Growing low-input high-diversity grassland species for biofuels

Tilman *et al.* (2006) grew highly diverse native prairie grassland species on degraded soils, used no or low inputs, and irrigated only in the first year that the plants were established. The biomass yielded from these low-input high-diversity grassland species provided more usable energy and more GHG reductions than corn ethanol or soybean biodiesel. Yields of high diversity grasslands species were 238% greater than monoculture yields after a decade. The low-input high-diversity grassland species were carbon negative and led to net sequestration of atmospheric CO_2 across the full life-cycle of biofuel production and combustion. Tilman *et al.* (2006) estimate that using 500 billion hectares of abandoned and degraded land to grow biofuels could replace 13% of petroleum consumption and 19% of global electricity consumption. Resistance to disease and exotic species is maximized in high-diversity plant mixtures, as is habitat for wildlife including pollinators, which may provide pollination services to adjacent crops. Soil fertility may also be increased over time and reduce erosion rates compared to traditional crops on tilled prairie (Tilman *et al.* 2006; Groom *et al.* 2008).

Ligno-cellulosic feedstock produced from short-rotation purpose-grown trees could reduce some adverse environmental impacts. For example, multiyear rotations allow extended periods between harvests, which limits land disturbance (Hinchee *et al.* 2009). In addition to ligno-cellulosic biofuels and traditional forest products, harvests can also produce power through direct firing, co-firing or wood pellet systems (Hinchee *et al.* 2009). Pressure to increase production of woody biomass for biofuels could lead to the conversion of natural forests to plantations. However, if the land was previously cleared for other purposes, this can lead to benefits for biodiversity and GHG reductions through land restoration (Groom *et al.* 2008). Differences in silvicultural systems for biofuel feedstock production can have different effects on biodiversity. For example, short rotation forest plantations for feedstock production may have negative effects on biodiversity because stands of small diameter trees lack the structural heterogeneity of natural forest stands, offering less wildlife habitat. But, if smaller diameter trees are harvested from forest stands leaving older trees and maintaining stand heterogeneity, this can lead to positive effects on biodiversity (see Fletcher Jr. *et al.* 2011). Although genetically modified trees could also provide biomass that can be more easily converted to biofuels, they do pose certain risks, such as dispersal of pollen, seeds or propagules, which can contaminate native species and wildlife, and will have to be strictly regulated before going into commercial production (Hinchee *et al.* 2009).

Ligno-cellulosic biofuels can provide opportunities to reduce GHG emissions. The Intergovernmental Panel on Climate Change (IPCC 2011) concludes, based on climate change mitigation objectives, that ligno-cellulosic biofuels to replace gasoline, diesel and jet fuels, advanced bio-electricity options and bio-refinery concepts can offer competitive deployment of bioenergy for the 2020 to 2030 timeframe. Combining bioenergy and carbon capture and storage using biomass raises the possibility of removing greenhouse gases from the atmosphere in the long term—a necessity for substantial overall reductions of such gases. However, this assumes limited adverse indirect effects (IPCC 2011). Ligno-cellulosic technology is currently in the research and development phase: there is still much need for research on an effective, economical and large-scale chemical transformation process for cellulosic biofuels (Nigam and Singh 2011; Sanderson 2011). Current research involves genetic modification of biological agents required to break down cellulose, as well as the production of plant breeds to increase yields, pest and frost resistance. Further technological advances, could potentially improve efficiency and bring down production costs. In addition, emerging technologies are shifting energy conversion efficiencies thereby creating the possibility of mitigating, though perhaps not removing entirely, some of the drawbacks with bioenergy production.

The integration of co-products from biofuels refineries can produce large reductions in GHG emissions (varying greatly by fuel type), and boost revenues and value of a feedstock (Fairley 2011; UNEP/GRID Arendal 2011). For example, a biorefinery co-product that can be used as protein for animal feed replaces the need for soy cultivation, avoiding associated land-use and reducing GHG emissions (Gallagher 2008). Many second generation biofuels do not produce beneficial co-products such as animal fodder, which is a drawback compared to conventional biofuels (Farrell *et al.* 2006; Eickhout *et al.* 2008; Gallagher 2008). Nevertheless, some research in this area suggests that there are some potential useful co-products to be obtained from second generation biofuels. Dale *et al.* (2010) considered ammonia fibre expansion (AFEX) pre-treatment, which produces highly digestible cellulosic biomass for ruminants, and leaf protein concentrate (LPC), made by coagulating the juice of certain fresh green leaves to produce a cheap yet nutritious protein-rich constituent of animal feed. Both techniques can be used on a multitude of ligno-cellulosic feedstocks. Only LPC has been used in commercial applications (only one plant produces it so far), but AFEX treated rice straw has successfully been added to animal feed.

Double crops have the potential to produce significant amounts of biofuels without competing with food production or requiring extra land (Tilman *et al.* 2009)**.** Double crops are grown between summer growing seasons of conventional row crops. They are typically winter annual grasses or legumes that are planted in autumn and harvested the following spring, before planting the next season of food crops. Double crops have potential environmental benefits, such as taking up nutrients that would otherwise have caused environmental degradation; protecting the soil against erosion; and enhancing soil fertility and soil organic matter because of root biomass left over from double crops (see Dale *et al.* 2010). Dale *et al.* (2010) considered aggressive double cropping in corn fields in modelling exercises to increase total biomass per hectare and integrate food and fuel production, and found it beneficial to several environmental parameters, including GHG emission reductions. Furthermore, Dale *et al.* (2010) found that if a double crop is used, more corn stover can be removed for biofuel production. However, there are some drawbacks to double cropping, such as decreased grain yields and increased nitrogen fertiliser application, and therefore higher nitrate emissions.

There is much interest and optimism in algal biofuels, which have been cited as the only renewable biofuel source that has the potential to completely displace petroleum-derived transport fuels (Chisti 2008; UNEP 2009a). Research has shown that the oil content of algae could be 200 times more productive per hectare than a land-based crop (Nigam and Singh 2011). However, the argument that algae present options to reduce land pressures (e.g., UNEP 2009a) because they can be produced in aquatic environments (wetlands) illustrates the need for more impartial and broader ecosystem-based approaches (because algae-based systems actually shift pressures between biomes and do not necessarily reduce them). Currently, the production costs for algal biofuels are very high and technical capacity to produce large quantities has not yet been achieved. Still, there is potential for significant improvements of feedstock's and processing through genetic engineering or synthetic biology (Nuffield Council on Bioethics 2011).

BOX 1.3: Some guidelines on approaches to feedstock production

The Nuffield Council for Biofuels (2011) propose that the development of new biofuels should be centred on abundant feedstocks that follow the unifying principles listed below:

1. can be produced without harming the environment or local populations;
2. are in minimal competition with food production;
3. need minimal resources, such as water and land;
4. can be processed efficiently to yield high-quality liquid biofuels; and
5. are deliverable in sufficient quantities.

Groom et al. (2008) suggest the following policy recommendations "to promote sustainably grown, biodiversity-friendly biofuels":

1. Evaluate the entire life cycle of biofuel production, use, and waste disposal to calculate the ecological footprint of any biofuel.
2. Require that the sustainability of biofuel feedstock production be assessed, and promote only biofuels that can be produced sustainably.
3. Select species with high conversion efficiencies to minimize the land area needed to produce biofuels. This will generally include ligno-cellulosic feedstocks for next-generation biofuel production and, most promisingly, microalgae.
4. Encourage restoration or reclamation of degraded areas for biofuel cultivation, wherever appropriate.
5. Prohibit clearing of natural areas to increase area under cultivation.
6. Ensure that feedstock production does not adversely affect ecosystem processes and sensitive habitats and investigate production methods that may enhance ecosystem processes over time.
7. Promote use of energy crops that can be grown with low fertilizer, pesticide, and energy inputs in most settings.
8. Promote use of native and perennial species.
9. Prohibit use of species that can become invasive.
10. Promote polyculture to reduce soil depletion and create biofuel cropping systems that can be used by a greater diversity of wild species.
11. Employ conservation tillage or other appropriate techniques to conserve soils.
12. Measure the greenhouse gas emissions over the biofuel production and use life cycle, and promote only those biofuels that are based on feedstocks and refining methods that are net carbon neutral or that sequester carbon.

2. GOVERNMENT REGULATIONS, SUSTAINABILITY CRITERIA AND CERTIFICATION SCHEMES

Many Governments and initiatives are applying and/or developing criteria as a tool to achieve sustainable biofuel production. At least 29 initiatives (as of 2009) were being led by national agencies, non-governmental organizations (NGOs), and associations to create, verify, and certify performance standards for the sustainable production of biomass and biofuels (UNEP 2009a). The International Energy Agency (IEA) cites 67 initiatives developing criteria for biofuel sustainability (IEA 2011). To be fully effective, criteria must be based on comprehensive life-cycle analyses (LCA) (see Section 4: Life-cycle analysis), and will not be able to ensure sustainability without effective criteria on indirect land-use change (iLUC) (see Section 5.3: Indirect land-use change), necessitating a precautionary approach in developing and sourcing biofuels. Further discussion is provided by Helldin *et al.* (2009) and van Dam (2010).

2.1 GOVERNMENT REGULATIONS

The rapid growth in biofuels has been due to government support, largely through biofuel mandates, which have been introduced in over 25 countries (Lane 2011; GSI 2012). Without this support, biofuels would not be cost competitive, especially in developed countries. However, mandates shift the burden of supporting the biofuel industry from the government, onto the consumers in additional costs at the pump (GSI 2012). As can be seen in Table 2.1 below, regulations are scattered across nations. These mandates (plus incentives and penalties) often transfer problems, such as unsustainable production, from a highly regulated country to a less regulated one (Robbins 2011). For example, the European Union (EU) will have to import a significant amount of its feedstocks from other countries to fulfil its targets. There has been concern about the effect of these targets and mandates on the rapid and often unchecked growth of the biofuels industry, including lack of adequate regulations in the developing world, and effects on food security and land use. Legislation is becoming increasingly fragmented and is hindered by unresolved policy questions. An example of this is the failure to resolve policies on indirect land-use change (iLUC) (see Section 5.3: Indirect land-use change) (Robbins 2011).

Biofuel targets and mandates which necessitate a net land-use change are faced with an inherent obstacle in achieving sustainability. Biofuel targets set by the EU and the United States of America (USA), as well as the possibility of increased biofuel targets in Brazil, China, Argentina and India have been projected to result in a large increase in the global area used for biofuel production. For example, a 14% increase in the harvested area of sugarcane and a 35% increase in oil palm area have been projected by 2017/18 (FAPRI 2008). Bertzky *et al.* (2011), focussing specifically on EU biofuel mandates, found that the impact of targets varies spatially and according to the crop, noting that cultivating woody instead of arable crops would have an overall positive effect (but see analysis by Louette *et al.* (2010) in Section 5.2, where the expansion of woody biofuel crops created a negative effect using BioScore), and that different biofuel policies have the potential to alter the status of biodiversity considerably by 2030, favourably or negatively. The Nuffield Council on Bioethics (2011) recommends that **biofuels mandates should maintain a certain degree of flexibility due to significant uncertainty, and the heterogeneity and complexities of various national circumstances**.

In 2010, almost 90% of the world's ethanol was produced by the USA and Brazil, and the EU was responsible for over half of the world's biodiesel production (REN21 2011). **The following summarizes the targets and the associated sustainability criteria of the three largest producers of biofuels (USA, Brazil and EU):**

Table 2.1: A Sample of biofuel mandates by nation (from Sorda et al. 2010; Lane 2011; Nuffield Council on Bioethics 2011; Robbins 2011)

Nation	Current Target	Future Target
Argentina	B7, E5	B10 by 2015
Brazil	B2, E22-23	B5 by 2013
Canada	B2, E5	*
USA	Biodiesel: 1.0 billion gallons; 0.91% Advanced biofuels: 2.0 billion gallons; 1.21% Cellulosic biofuels: 3.45 – 12.9 million gallons; 0.002 – 0.010% Total renewable fuels: 15.2 billion gallons; 9.21% 7.5 billion US gallons (approximately 28 billion litres) of renewable fuel be blended with gasoline by 2012	36 billion gallons of biofuels by 2022 21 billion gallons from ligno-cellulosic biofuels
Costa Rica	B20, E7	*
EU	5.75% renewable transport fuel	10% renewable transport fuel by 2020
China	N/A	E10 by 2020
India	E5	20% biofuels by 2017
Japan	N/A	10% biofuels by 2030
Australia	Queensland: E5 New South Wales: E10	*

• *B refers to biodiesel and E to ethanol. The number beside B or E is the percentage blend into transport fossil fuel.*

** Information not available at the time of publication.*

i. Renewable Energy Directive (RED)

Through the **Renewable Energy Directive (RED)**, the European Commission has developed mandatory regulatory standards that apply to all biofuels feedstocks used to meet the renewable energy targets, **whether grown in or imported to the EU** (EU 2009).

Some of the main EU RED targets (Swinbank 2009; EU 2009):

- By 2020, all member state must ensure that a minimum of 10% of transport fuels be composed of renewable sources, mostly biofuels.
- As of 2008, plants in operation must demonstrate that their biofuels offer at least 35% in GHG emissions reductions.
- As of 2017, existing plants must demonstrate GHG emissions reductions of 50%.
- As of 2017, new plants from this date will have to demonstrate GHG emissions reductions of 60%.

Some EU RED sustainability criteria (Swinbank 2009; EU 2009):

- Biofuels crops must not be grown from land with "recognized high biodiversity value" in or after January 2008 (E.g. primary or undisturbed forest, species rich grassland, protected areas);

- Biofuels crops must not be grown from land with high carbon stocks (E.g. wetlands, continuously forested areas);
- "The Commission shall report every two years … on the impact on social sustainability in the Community and in third countries of increased demand for biofuel, and on the impact of EU biofuel policy on the availability of foodstuffs at affordable prices, in particular for people living in developing countries, and wider development issues. Reports shall address the respect of land use rights";
- "The use of land for the production of biofuels shall not be allowed to compete with the use of land for the production of foods".

There are limitations to the RED sustainability criteria. While the criteria can offer GHG emissions reductions, increased pollution, especially of rivers and ground water, resulting from intensive biofuel production methods can still occur (Bourgeon and Tréguer 2010). In the EU RED sustainability criteria, fertiliser use is hardly mentioned. While the criteria mention on-site N_2O emissions, they do not necessarily account for off-site emissions. Consideration of water use is also limited (EU 2009). Modelling experiments by Frank *et al.* (2012) suggest leakage[8] effects, due to indirect land-use change (iLUC) (see Section 5.3: Indirect land-use change) into the food and animal feed sectors and countries outside Europe, limit the effectiveness of RED sustainability criteria. It was estimated that blending mandates of the EU would result in iLUC of between 4.7 million hectares (approximately the size of the Netherlands) and 7.9 million hectares (approximately the size of Republic of Ireland) and large increases in GHG emissions (Bowyer and Kreschmer 2011). Therefore, biofuels that are considered "sustainable" under the EU RED could in fact pose negative environmental effects. Frank *et al.* (2012) suggests wider land-use change policies targeting all drivers of land-use change and not only the biofuels sector to increase the effectiveness of policies in achieving biodiversity conservation (see Section 5: Land use).

ii. US Renewable Fuel Standard

Unlike the European RED sustainability criteria, which mandate the minimum required proportions of biofuels to be used in transport fuels, the USA's Renewable Fuel Standard[9] (RFS2) sets absolute minimum quantities for biofuels. Specifically, the standard requires that:

- By 2012, 7.5 billion gallons (approximately 28 billion litres) of renewable fuel be blended with gasoline by 2012;
- By 2015, 15 million gallons should be derived from conventional biofuels and 0.1 billion gallons should come from cellulosic biofuels;
- By 2022, 36 billion gallons (approximately 136 billion litres) of USA transport fuel should be derived from biofuels by 2022;
- By 2022, 21 billion gallons of biofuels should come from cellulosic biofuels.

The RFS2 also requires GHG emissions reductions of 50% for advanced biofuels and 20% GHG emissions reductions for conventional biofuels (EPA 2010; Sorda *et al.* 2010).

The USA currently uses 40% of its corn to make biofuels, which means that if all the corn in the USA was used for biofuels, this would only supply one quarter of transport fuel needs (Wise 2012). Furthermore, vehicles sold today in the USA can only tolerate fuel composed of about 10% ethanol.

iii. Brazil's Proálcool program

Brazil has one of the most mature and advanced biofuels programs. The national alcohol program, *Proálcool*, was introduced in 1975 due to the 1970 oil crisis and focuses on ethanol production from sugarcane (Sorda *et al.*

8 "Leakage" refers to an indirect impact where an activity in a certain place affects activities outside the system boundaries

9 Renewable Fuel Standard: http://www.epa.gov/otaq/fuels/renewablefuels/index.htm

2010). Fuel-Flex vehicles, which run on either ethanol or gasoline, were also successfully introduced to the country. Brazil's sugar and ethanol production account for 3.6 million jobs and 3.5% of the gross domestic product (GDP). Fifty per cent of the country's sugar cane supply is used for the production of ethanol (de Almeida *et al.* 2008). Brazil's ethanol is the most price competitive biofuel in the world, at between US$0.23-0.29 per litre (Kojima and Johnson 2006). This success can partly be attributed to high levels of land productivity and subtropical climate, coupled with limited needs for irrigation. Sugarcane also has very high energy density compared to other feedstocks. Furthermore, processing plants can generate all their electricity through the use of bagasse, a by-product of sugarcane (de Almeida *et al.* 2008). However, demand in sugar for food consumption has forced the government to reduce its blending targets from 25% to 22-23% to prevent further increases in ethanol prices (Robbins 2011).

Unlike the USA and EU biofuel policies, Brazil's policies incorporate a significant amount of flexibility in that the mandates are not binding (FAO *et al.* 2011). Production and consumption decisions are made based on current relative prices of oil and ethanol. Brazilian processing plants can modify the share of sugarcane used for ethanol or sugar production, and the Fuel-Flex cars can use both fuels (FAO *et al.* 2011). There are currently no direct subsidies for ethanol production in Brazil; but, there is preferential treatment of the ethanol industry over gasoline producers. Brazil also has a biodiesel program, the National Program on Biodiesel Production and Usage (PNPB), with a mandate of 2% biodiesel blend into fossil diesel from 2008-2012, and an increase to a 5% blend from 2013. The biodiesel program, though, is not yet cost competitive and receives direct subsidies (Colares 2008).

2.2 VOLUNTARY STANDARDS

Voluntary standards and their associated certification schemes are under development by various initiatives, industry or other interested groups such as NGOs, and are often promoted by multi-stakeholder alliances. They typically set out criteria or principles that producers can adhere to in order to get accreditation to that standard. They lack the legal clout of regulatory standards, but can be applied widely. The Netherlands Agency (2011) provides guidance on the selection of certification schemes, tools and information for biomass actors, and outlines a variety of voluntary certification schemes that have become operational for the production, processing and trade of biomass, for agricultural and forestry products (e.g., International Sustainability and Carbon Certification (ISCC), Forest Stewardship Council (FSC), Roundtable on Sustainable Biofuels (RSB)). Crop-specific voluntary initiatives such as the Better Sugar Cane Initiative, the Roundtable on Responsible Soy (RTRS) and the Roundtable on Sustainable Palm Oil (RSPO) have developed or are developing voluntary standards that consider, amongst other things, the biodiversity impacts of biofuel production. A comparison of these initiatives can be found in Hennenberg *et al.* (2009) and UNEP (2009a). More detailed examples of sustainability standards under development by the Global Bioenergy Partnership and the Roundtable on Sustainable Biofuels are provided in Box 2.1 and 2.2, below.

Standards and certification and accompanying mechanisms need to be further developed to consider all relevant environmental and social impacts. It has been suggested that the current diversity of standards calls for harmonization to ensure agreed environmental aims are met. Some of the schemes mentioned above are making good progress in developing consensus on standards and tools for monitoring and certification. But there are concerns regarding the effectiveness of voluntary frameworks, especially under globalized conditions. Buyx and Tait (2011), for example, point out that each member state of the EU setting its own standards would lead to 27 variations. Market-based certification usually only covers a fraction of the product market creating the appearance of sustainability whilst unsustainable production continues (UNEP 2009a). There are therefore numerous calls for international agreed standards and frameworks, for example, the Cramer Commission (2007), the United Nations Environment Programme (UNEP 2009a), Buyx and Tait (2011), and the International Energy Agency (IEA 2011). Robbins (2011) suggests the development of a standard for biofuels by the International Organization for Standardization (ISO). One reviewer noted that the ISO is already developing sustainability criteria for bioenergy; however limited information is currently available. Most recognize the need to implement international standards without creating unwanted trade barriers, especially for developing countries, and call for a mandatory regulatory framework under a UN agency or instrument.

BOX 2.1: The Global Bioenergy Partnership (GBEP)

The Global Bioenergy Partnership (GBEP) (http://www.globalbioenergy.org/) brings together decision-makers, private sector, civil society and international agencies with expertise in bioenergy "to organize, coordinate and implement targeted international research, development, demonstration and commercial activities related to the production, delivery, conversion and use of biomass for energy, with a focus on developing countries"[10]. GBEP provides a forum to develop effective policy frameworks and enhance international collaboration to promote sustainable biomass and bioenergy development. Priority areas for the immediate programme of work of the GBEP include: facilitate the sustainable development of bioenergy; test a common methodological framework on GHG emission reduction measurement from the use of bioenergy; facilitate capacity-building for sustainable bioenergy; and, raise awareness and facilitate information exchange on bioenergy.

As of 14 August 2012, GBEP Partners comprise 23 countries and 13 international organizations and institutions. A further 22 countries and 11 international organizations and institutions are participating as observers. GBEP partners and observers produce most bioenergy globally, including liquid biofuels.

As of 30 November 2011, 24 indicators[11] for the three pillars of sustainability (social, economic and environment) have been identified and agreed (by consensus among GBEP partners). Considerable work is still required on methodologies for some of the indicators.

10 from GBEP website: http://www.globalbioenergy.org/aboutgbep/purpose0/fi/

11 GBEP report on indicators is available here: http://www.globalbioenergy.org/fileadmin/user_upload/gbep/docs/Indicators/The_GBEP_Sustainability_Indicators_for_Bioenergy_FINAL.pdf

BOX 2.2: The Roundtable on Sustainable Biofuels (RSB))

The Roundtable on Sustainable Biofuels (RSB) (http://rsb.epfl.ch) is an international multi-stakeholder forum hosted by the Swiss Federal Institute of Technology in Lausanne (EPFL), Switzerland. Its aim is to develop a global sustainability standard and to implement a practical certification system guaranteeing the social and environmental performance of biofuels. Presently, the RSB has over 130 member organizations from more than 30 countries. Membership is open to any organization working in areas relevant to bioenergy, including oil companies, fuel makers, large and small farmers, investors, governments, non-governmental organizations, United Nations agencies and research institutes.

The RSB's global certification standards (http://rsb.epfl.ch/page-67254-en.html) are developed through an open and transparent multi-stakeholder process, and describe requirements for sustainably produced biomass and biofuels for RSB certification. These voluntary standards are applicable to any region, feedstock or biofuel type, and cover the entire biofuel supply chain. The RSB standards continue to be updated and expanded as new technologies and knowledge become available. The primary use of the RSB global standards is certification, which uses a risk management approach and independent third party certification bodies.

The RSB has agreed on a 50% reduction in GHG emissions for biofuel blends compared to a fossil fuel baseline. RSB certified operators (biofuels-related organizations and stakeholders are referred to as "operators" by RSB in the context of certification) must also abide by GHG emissions requirements in the country/region where they operate.

More information on RSB stakeholder consultations on how it can best deal with the indirect land-use change (iLUC) problem is available in Section 5.3: Indirect land-use change.

Certification standards for the sustainability of biofuels could be found to be discriminatory and hence illegal under international trade law, if sustainable biofuels are treated more favourably than non-sustainable biofuels (GSI 2007; de Gorter and Just 2009). Discriminating between domestic and imported products based on processes or production methods used to produce them is prohibited to members of the World Trade Organization (WTO) (de Gorter and Just 2009). For example, a country may be challenged by the WTO if it were to treat imports differently based on a life-cycle analysis (LCA) of GHG emissions savings, supporting a mandatory certification scheme. Criteria also must be flexible enough for developing countries to meet under their prevailing local conditions and not act as a trade barrier. If countries or world regions, impose different GHG emissions requirements for biofuel production, this could also exclude certain regions or crops from trading with certain countries or regions. The GSI (2007) states that international consensus on sustainability standards for biofuels is necessary or they may not form a legitimate basis for regulations applied by importers. Most of the iLUC impacts caused by biofuels are actually driven by trade in biomass commodities (although biofuels are by no means unique in this regard). Trade, biofuels, sustainability, iLUC and biodiversity are therefore intimately linked.

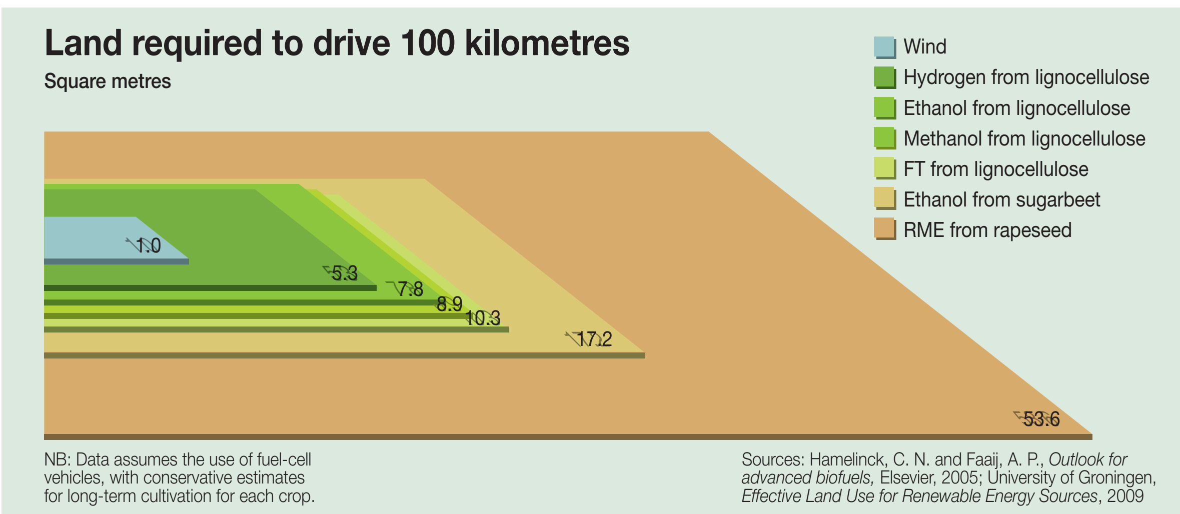
There is much debate on whether or not biofuels should be regulated more stringently than other agricultural commodities. Food security has a tendency to dominate agricultural objectives and is also dependent on sustainability. Nevertheless, a significant proportion of agricultural production does not support food security and can be challenged on ethical grounds, perhaps even more so than biofuels. Examples might include cosmetics, fibres for non-essential clothing and unhealthy diets. Whilst some argue that biofuels should be regulated more stringently than other agricultural products, others, backed by most scientific evidence and argument, support equal standards being applied to all agricultural commodities (see FAO 2008a; Gallagher 2008; de Gorter and Just 2009). De Gorter and Just (2009), argue that regulating GHG emissions for some uses of crops and not others is illogical from an economic viewpoint. For example, corn is used for beef, bourbon, high-fructose corn syrup and chemical products, but these uses do not generate energy. Therefore, there is no reason that corn ethanol should be more stringently regulated than other products made from corn.

It has been proposed that a comprehensive framework be developed to mitigate GHG emissions from agriculture, land use and land-use change (De Gorter and Just 2010). De Gorter and Just (2010) state that ethanol in itself is carbon neutral by definition; it is the practices used in biofuel production that cause a net increase or decrease in CO_2 emissions. Rather than regulating the negative impacts of biofuels through sustainability standards, it would be more effective to use specific taxes and subsidies that directly target environmental and policy goals across all crop production.

3. ASSESSING BIOFUELS AGAINST RENEWABLE ENERGIES AS WELL AS FOSSIL FUELS

Biofuels are one of many potential renewable energy options and comparisons should therefore be made amongst those options. Energy demand is projected to increase significantly in the coming decades (IEA 2009). Globally, biofuels now provide only 2% of total transport fuel but the International Energy Agency predicts that biofuels will provide approximately 27% of the world transport fuel by 2050 (IEA 2011). As a result, an integral part of energy strategies for both developing and industrialized nations is abundant, cheap, renewable and environmentally friendly energy (Gasparatos *et al.* 2011). However, much of the literature on biofuels implicitly assumes that biofuel production and use is an objective in itself simply because it is "renewable". The issue is, however, how does it perform compared to other renewable sources? There is of course attention to this in forums discussing wider energy interests and the Intergovernmental Panel on Climate Change (IPCC 2011) provides such a broader review of renewable energy as a whole. Nevertheless, in the literature available, life-cycle assessments of biofuels are usually done in relation to fossil fuels as opposed to other renewable energies. Figure 3.1 compares various renewable energy options in terms of land required to drive 100 km: wind energy requires 1 square metre of land, and hydrogen from ligno-cellulose requires 5.3 square metres, while rapeseed biodiesel requires 53.6 square metres. Therefore, conventional biofuels offer some of the least land-efficient renewable energy sources.

Figure 3.1: Land required to drive 100 kilometres



Credit: Riccardo Pravettoni-UNEP/GRID Arendal (http://www.grida.no/graphicslib/tag/biofuels)

Biofuels are essentially life-based solar energy systems and the most immediate comparison could be with artificial "solar power". Biomass has the lowest power density of all renewable energies, and therefore requires the largest amount of land per unit of energy produced. Biomass in land cover (agriculture or forestry) can generally store only about 1 to 6% of the solar radiation input (Woods *et al.* 2009) and still requires transformation into useful energy. By comparison technologies such as photo-voltaics (PV) and solar thermal power can make use of 9 to 24% of the solar radiation input, with recent averages of about 15% (Lightfoot and Green 2002; Green *et al.* 2007; World Energy Council 2007). Furthermore, solar systems can be installed on buildings requiring no additional land.

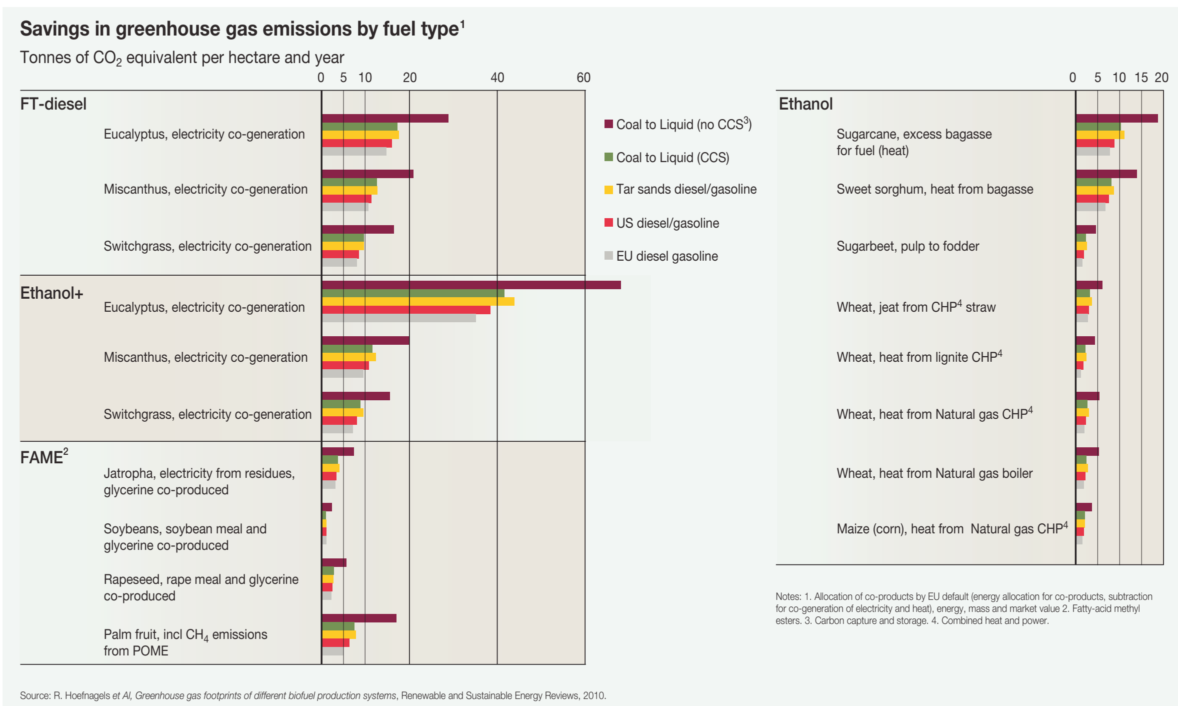
Any attempts towards sustainable energy for transportation will have to include liquid fossil fuels for the short- to medium-term. Millions of motor vehicles require a compatible liquid fuel to the existing technology in order to operate (Robbins 2011; Fairley 2011). To enable independence from imported petroleum in the longer term, it has been suggested that a more sustainable option would be for light vehicles to become to electric and for biofuels to be used for heavy vehicles (Savage 2011). There is a particularly strong argument for alternative liquid fuels for aviation transport due to the difficulties of re-engineering aircraft engines. But in the longer term, even these applications need not necessarily be based on liquid biofuels. Technologies already exist to produce artificial liquid fuels without a biomass feedstock (although an energy source is still required). Kubiak and Sathrum (Science 2011) and Rosen *et al.* (2011) report simple artificial technologies to capture energy from the sun, convert it to electrical energy and "split" carbon dioxide into carbon monoxide and oxygen. Reece *et al.* (2011) report the development of a simple "artificial leaf" to further mimic photosynthesis and split water into oxygen and hydrogen. These are further examples of first steps in producing artificial fuels that could potentially replace biofuels.

Despite advancing science and technology, cost efficiencies and deployment are primary concerns. But here too, rapid changes are occurring. The Intergovernmental Panel on Climate Change (IPCC 2011) notes the exponential decreases being achieved in the costs of production of energy from PV cells whereas costs for liquid biofuels, based on current technology, show meagre improvements by comparison. For these, and other, reasons the IPCC (2011) concluded that the literature indicates that long-term objectives for renewable energy and flexibility to learn from experience would be critical to achieve cost-effective and high penetrations of renewable energy.

4. LIFE-CYCLE ANALYSIS (LCA)

Life-cycle analysis is an accounting method widely used to assess, and compare, the carbon footprint of transportation fuel types from "well to wheel". This information helps determine which biofuels have the most improved emissions savings compared to fossil fuels. This is of direct relevance to biodiversity considerations because GHG benefits are a factor in biodiversity trade-offs and in some cases, particularly with land-use effects, the GHG emissions in question arise directly from biological resources (e.g., forests). Even though the carbon emitted when burning biofuels is thought to equal the carbon taken up by the crop during plant growth (but see further consideration of this below), energy inputs required for plant growth, harvest, transport, processing and distribution, also release carbon. Figure 4.1 shows large variations in GHG emissions savings for different biofuel production systems. Moreover, land-use change, such as deforestation to clear land for biofuels plantations, as well as indirect land-use change (iLUC) (see Section 5.3: Indirect land-use change) release large quantities of carbon (see Sanchez *et al.* 2012) but are usually not considered in LCAs. There are many limitations to LCA, some of which are described below, but also many opportunities to improve this method.

Figure 4.1: Savings in greenhouse gas emissions by fuel type



Credit: Nieves Lopez Izquierdo (http://www.grida.no/graphicslib/tag/biofuels)

In LCA, the reference fuel used to compare the carbon footprint of a type of biofuel should be given consideration depending on the particular context. Figure 4.1 shows wide variations in the carbon footprint of biofuels depending on which production system was used and which type of fossil fuel was used as a reference point. Energy allocation for co-products of biofuel production, as well as co-generation of electricity and heat, can increase GHG emissions savings of a biofuel in LCA. The method of production of the fossil fuel baseline, including whether carbon capture and storage (CCS) was used, can also affect the outcome of LCA. Sometimes a fossil fuel may not always serve as the best reference point in LCA. For example, modern biofuels can be used instead of wood burning for home cooking in developing countries, which reduces human health risks and environmental costs. In this case, using wood burning as a reference point would better illustrate the advantages (or disadvantages) of using modern biofuels in this particular context. Another consideration concerns the fundamental flaw in the application of LCA of ignoring GHG emissions due to indirect land-use change (iLUC) (see Section 5.3: Indirect land-use change) (Searchinger *et al.* 2008); some argue (e.g., de Gorter and Just 2010) that expanding LCA to account for all indirect changes would mean measuring indirect effects in the oil sector for a fair comparison. For example, the indirect effects of oil production in the Ecuatorial jungle, or the indirect emissions from military expenditures protecting Middle East petroleum would have to calculated, where a conservative estimate for the latter would double GHG emissions from gasoline. Therefore, when conducting an LCA on a biofuel, consideration must also be given to type of fossil fuel used as a baseline in LCA to make a fair comparison.

Another flaw in GHG accounting in many LCAs is that biogenic CO_2 emissions are *de facto* ignored. Biofuels are assumed to be climate neutral because the carbon released when burning biomass approximately equals the carbon absorbed from the atmosphere by biomass re-growth. However this underestimates the importance of the time as it may require decades or even centuries, before this atmospheric carbon is taken up again by plant regrowth. As an example, Cherubini *et al.* (2011) provide a case study of a bio-refinery system producing transportation biofuels, biochemicals and bioenergy from forest wood. When the delay factor is included in the assessment, the GHG emissions savings of the bio-refinery are drastically reduced and its contribution to climate change becomes approximately similar to that of the respective fossil fuel reference system. Similarly, Holtsmark (2010) concludes that wood harvesting and combustion are not carbon-neutral activities, even if "sustainable" and not involving land-use change, and that increasing the use of wood from otherwise sustainably managed boreal forest to replace coal in power plants will create a carbon debt that will only be repaid after 150 years. If the wood is used to produce "second generation" liquid biofuels and replaces fossil diesel, the payback time of the carbon debt is estimated to be 230 years. Different sources of wood also have different implications for GHG emissions in LCA. However, the GHG savings from bioenergy obtained through increased use of waste from different forest-related industries can deliver positive benefits. The challenge is to measure these GHG contributions with unit-based indicators to be included in LCA. The inherent difficulties to quantify this effect have so far hindered accurate estimation. The European Energy Agency (EEA) Scientific Committee (2011) recommends that accounting standards for GHG emissions fully reflect all changes in the amount of carbon stored by ecosystems, including the ecosystem carbon uptake and loss, resulting from production and use of biofuels.

Failure to account for what the land would have been used for, if it was not for biofuel production, is a basic error in the assumption of carbon neutrality for biofuels (Haber *et al.* 2012). Biofuel crops grown on a plot of land are soon harvested, processed and combusted. However, if this land was not used for biofuels, plants and trees growing on this land would continue to absorb carbon and sequester it in the soil (Haber *et al.* 2012). If biofuels crops are grown at the expense of forest, which can be substantial carbon sinks, this foregone carbon sequestration is not considered in LCAs. Using biofuels, instead of fossil fuels, can result in more carbon remaining sequestered underground as fossil fuels, but less carbon stored by plants and in soils. Biofuels may reduce GHG emissions only to the extent that the carbon remaining sequestered as fossil fuels outweighs the carbon lost from plants and soils (Haber *et al.* 2012). Therefore, LCA needs to account for rates of plant growth, with and without bioenergy production, and changes in carbon stored in soils and plants caused by bioenergy production.

LCA should include much more than GHG considerations; a broad range of assessment impact categories are necessary for a more holistic assessment (UNEP/GRID Arendal 2011). UNEP (2009a) assessed a representative sample of LCA studies on biofuels and concluded that less than one third presented results for acidification and eutrophication, and only a few for toxicity potential (either human toxicity or eco-toxicity, or both), summer smog, ozone depletion or abiotic resource depletion potential, and none on biodiversity. A recent national-level LCA report, comparing biofuels to fossil fuels used in France, included an analysis of eutrophication, photo-oxidation and human toxicity potential for all biofuels, and took into account potential N_2O emissions using simulations (BIO Intelligence Service 2010). Groom *et al.* (2008) suggest that the ecological footprint of a biofuel should be calculated, which goes beyond LCA. Factors that should be included in the ecological footprint of a biofuel include greenhouse gas emissions over its entire life-cycle; energy efficiency or net energy balance over the life-cycle of the biofuel combined with its fuel yield per hectare; relative levels of water, fertilizer, and pesticide use; and amount of energy required to cultivate and refine the feedstock. Local growing conditions and agricultural practices will have a strong influence on the impacts and sustainability of biofuel feedstocks.

LCA methodologies require further development. LCA is an on-going process that can provide useful insight by organising and prioritising information needs, but is not necessarily a precise final product (McKone *et al.* 2011) Inconsistencies in assumptions used in various assessments often do not allow for comparable results between fuel types (Mandil and Shihab-Eldin 2010). Harmonizing rules on LCAs should include setting reasonable guidelines and assumptions for methodological issues: UNEP (2009a) recommends that rules on how to carry out LCAs be harmonized, particularly for a common set of impact indicators. Associated uncertainty of key parameters need to be addressed: these include water-consumption and pollution issues, allocation rules of impacts on co-products, N_2O emission rates, land use, carbon stocks and technology progress (UNEP 2009a). Guidance and best-practices are needed to address uncertainty and variability with respect to data quality; data corroboration and validation; and temporal, spatial and technological variability (McKone *et al.* 2011). The deficiencies in LCA may only be overcome through the use of complementary analytical approaches such as land use and resource mapping, and macro-economic modelling, which may better capture the impact of biofuels in their spatial context (UNEP 2009a). Some argue (e.g., Pfromm *et al.* 2011) that an engineering mass balance/unit approach may be a more robust method to assess sustainability of biofuels than the LCA method, which is in essence an accounting procedure that has been criticized for lacking a coherent scientific foundation (UNEP 2009a).

Seven grand challenges for applying LCA to biofuels have been identified by McKone *et al.* (2011):

1. Understanding farmers, feedstock options, and land use;
2. Predicting biofuel production technologies and practices;
3. Characterizing tailpipe emissions and their health consequences;
4. Incorporating spatial heterogeneity in inventories and assessments;
5. Accounting for time in impact assessments;
6. Assessing transitions as well as end states; and
7. Confronting uncertainty and variability.

5. LAND USE

Biofuel production has increased, yet land is a resource that is declining globally (UNEP/GRID Arendal 2011). As the world population continues to grow and food demand is expected to rise, many sectors are competing for the same land. Biofuels is only one of the competing industries. Several reports have projected that biofuels could fill 20-50% of the world's energy demand in the coming decades. This would require double or triple the amount of plant material currently being harvested on earth (EEA Scientific Committee 2011).

BOX 5.1: Is there enough land left on earth to feed a growing population and produce biofuels? You do the math.

Cropland and pastures currently occupy about **40% of the global land surface** (Asner *et al.*, *in* Foley *et al.* 2005) and agriculture alone is responsible for approximately **85% of the world's consumptive water use** (Gleick 2003 *in* Foley *et al.* 2005). 1.4 billion people live in areas with diminishing ground water levels, mostly in the Near East/North Africa and South Asia, and this is likely to worsen due to climate change (FAO 2009).

The world's population is predicted to reach **9.1 billion people by 2050**, which would require a **70% increase in food production** (FAO 2009). The FAO predicts that 80% of the production increase would come from yield increases and 20% from expansion of cropland, mostly in developing countries. This would require a 5% increase in the area land used for agriculture, or an **additional 70 million hectares** (Mha). However, as land use is expected to decrease by 50 Mha in developed countries, developing countries would have to increase their productive agricultural area by about 120 Mha.

The current global land used for biofuel feedstock production is approximately 30 Mha (IEA 2011). The International Energy Agency (IEA) (2011) estimates that **biofuels could fill 27% of the world energy needs by 2050 and would require a total of 100 Mha of agricultural land to produce**.

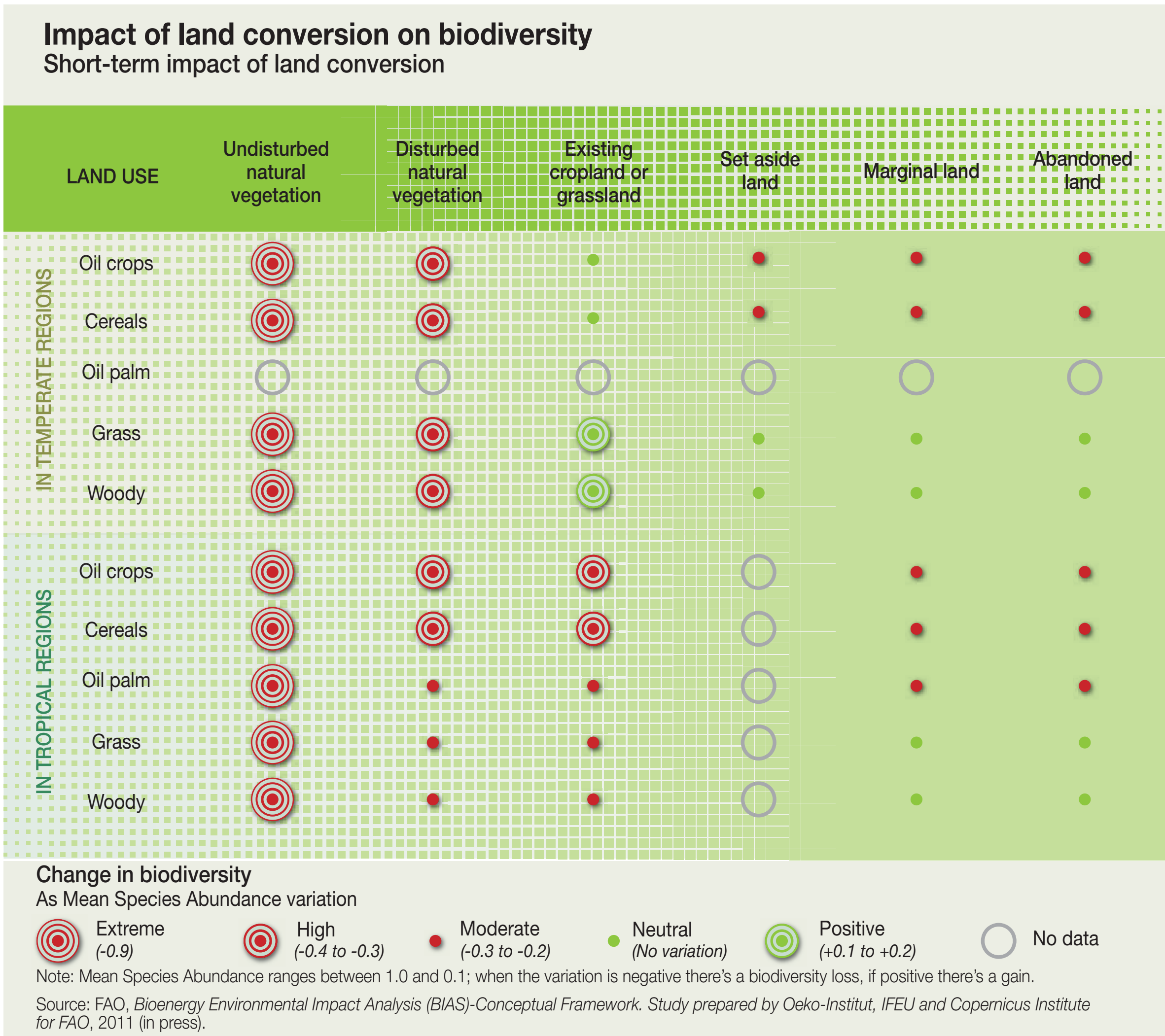
We also need to account for preserving natural habitat to protect the crucial ecosystem services that we depend on. Much of this agricultural and biofuel production expansion would be at the expense of this natural habitat, which is already being degraded at an alarming rate (MEA 2005).

Land-use change from biofuel production exacerbates the risk of losing biodiversity and ecosystem services (UNEP/GRID Arendal 2011). The impact varies according to location of cultivation and agricultural practices. Figure 5.1 below shows that the most negative short-term impacts from biofuels on biodiversity come from conversion of undisturbed natural vegetation. Beneficial impacts on biodiversity were only expected from conversion of cropland or grassland to grass feedstocks or woody feedstocks for biofuels. Neutral impacts were recorded on set-aside, marginal and abandoned land for only grass or woody feedstocks (UNEP/GRID Arendal 2011).

Biofuel land requirements often exceed a country's own resources, creating a spill-over into other countries and regions (UNEP/GRID Arendal 2011). For example, it has been estimated that most European countries do not have sufficient land area to fulfil current biofuels blending mandates in the EU Renewable Energy Directive (RED) (UNEP/GRID Arendal 2011). Use of water is also a critically limiting factor for the development of biofuels. Figure 5.2 below shows that the global trade in biofuel crops has created a "virtual water exchange" where some countries with limited water resources export their water in the form of biofuels.

Different feedstocks and fuels, local variables and production practices have different energy input and output, and land use impacts. The bulk of GHG emissions from biofuels may be in large part due to land-use change, and these GHG emissions vary greatly by energy crop. For example, Figure 5.3 illustrates that peatland tropical rainforest in Southeast Asia emits 1797 tonnes of CO_2 per hectare when converted to oil palm, while feedstocks grown on degraded land, result in reductions of 90 tonnes of CO_2. Figure 5.4 (below) illustrates that the land required for biofuels varies widely for different feedstocks under different local conditions. For example, sugarbeet in Europe requires 0.27 hectares of land to produce one ton of oil equivalent in ethanol, whilst soybean in the USA requires 2.63 hectares to produce one ton of oil equivalent in biodiesel.

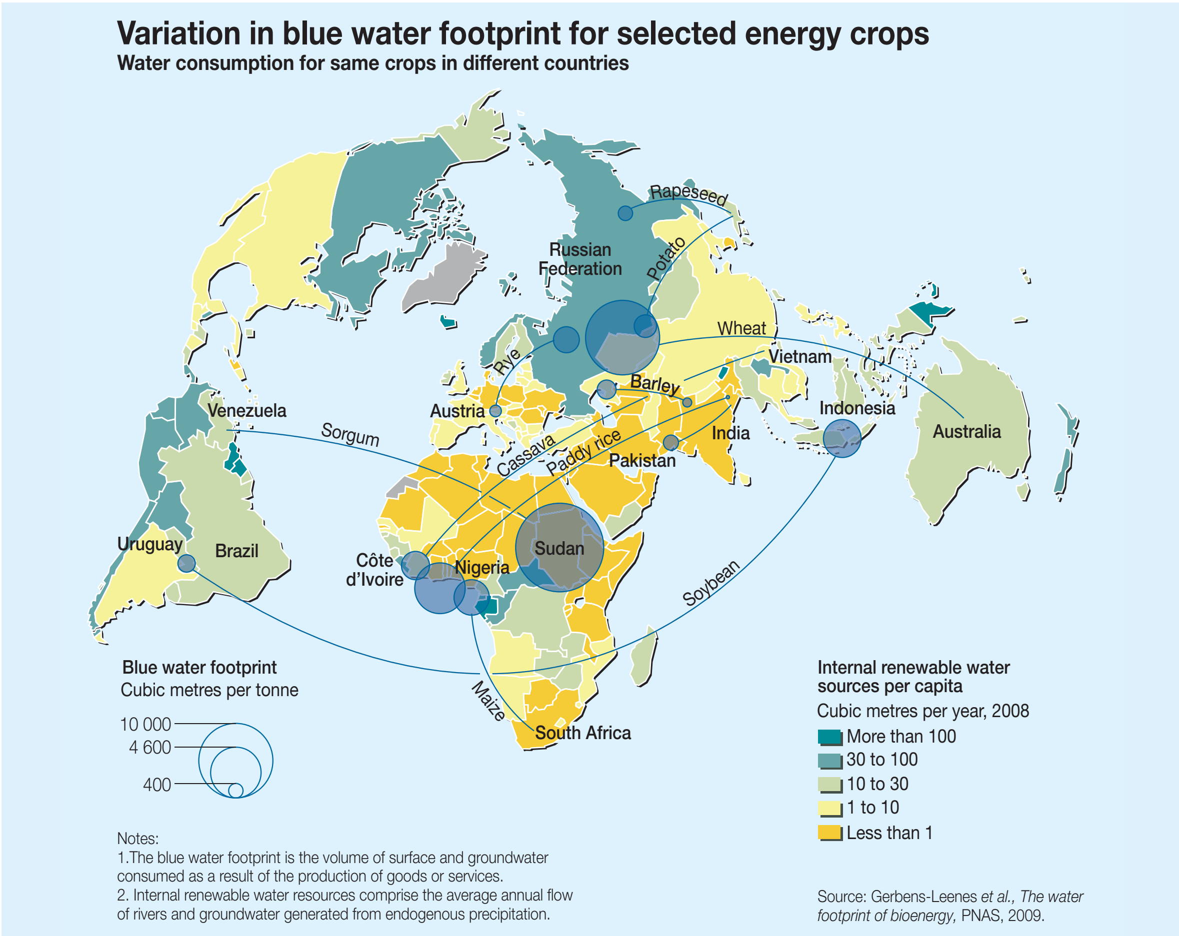
Figure 5.1: Impact of land conversion on biodiversity



Credit: Riccardo Pravettoni, UNEP/GRID Arendal (http://www.grida.no/graphicslib/tag/biofuels)

Improving the efficiency of feedstock production, conversion and use can help decrease pressure on land, water and other resources. Different biofuels have different efficiencies in growth, conversion and end-uses (UNEP/GRID Arendal 2011). The "chain of efficiency" considers input and outputs required for a feedstock and can also help national planning processes identify the most suitable feedstock for a country, region or local context. The best use of land, water and other resources depends on a country's specific conditions and trade-offs between policy objectives (UNEP/GRID Arendal 2011).

Figure 5.2: Variation in blue water footprint for selected energy crops



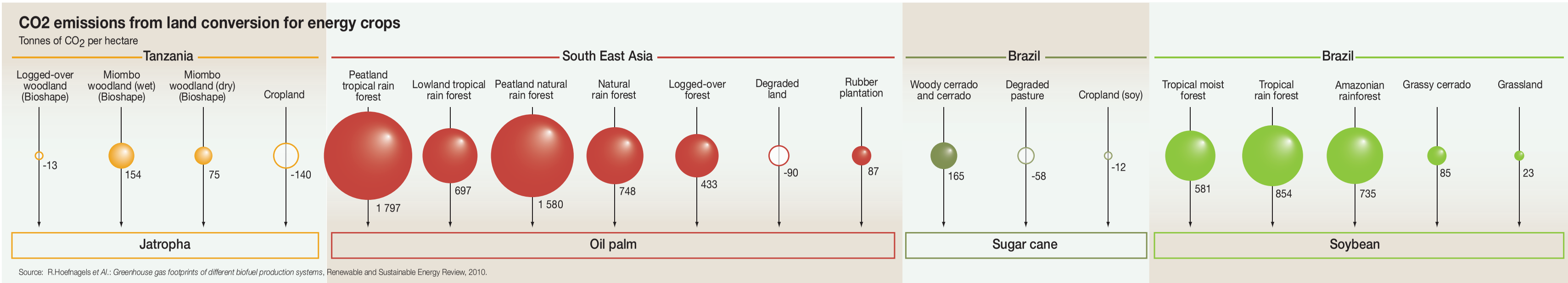
Credit: Riccardo Pravettoni, UNEP/GRID Arendal (http://www.grida.no/graphicslib/tag/biofuels)

5.1 GROWING BIOFUELS ON DEGRADED LANDS

Much has been made of the potential to reduce local land pressures, and in some cases, also improving biodiversity, by growing energy crops on "degraded", "marginal", "abandoned" or "waste" land. Whilst intuitively this approach is attractive, recent work on the topic is showing it to be not so simple. Not least of the issues is the lack of consensus on definitions of this kind of land. For example, should secondary forest be included as "degraded" lands? Some "degraded" lands support high conservation value species and the livelihoods of local communities. What may be considered marginal or degraded in one country may constitute a primary source of livelihoods in others, especially for the rural poor. Moreover, degraded lands undergoing restoration can be important carbon sinks.

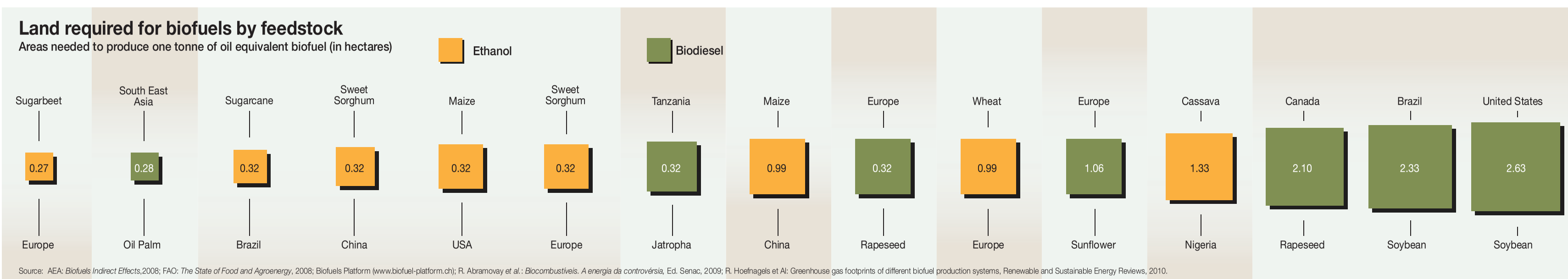
Biofuel crops grown on abandoned agricultural land will probably not generate a high percentage of the world's energy demands, except potentially at the local level in some African countries. Campbell *et al.* (2008) estimate the global area of abandoned agriculture land to be between 385-472 million hectares and the global potential for bioenergy (in dry biomass, not liquid biofuels) on this land to represent less than 8% of the primary energy demand. If this dry biomass were converted to liquid biofuels, it would cut the net energy to half the amount. The bioenergy potential from abandoned agricultural land was the largest in the USA, Brazil and Australia, as can be seen in Figure 5.5 below. However, this bioenergy potential represents less than 10% of the primary energy demand for most countries in North America, Europe and Asia, but many times the demand for many African nations (Campbell *et al.* 2008).

Figure 5.3: CO_2 emissions from land conversion for energy crops



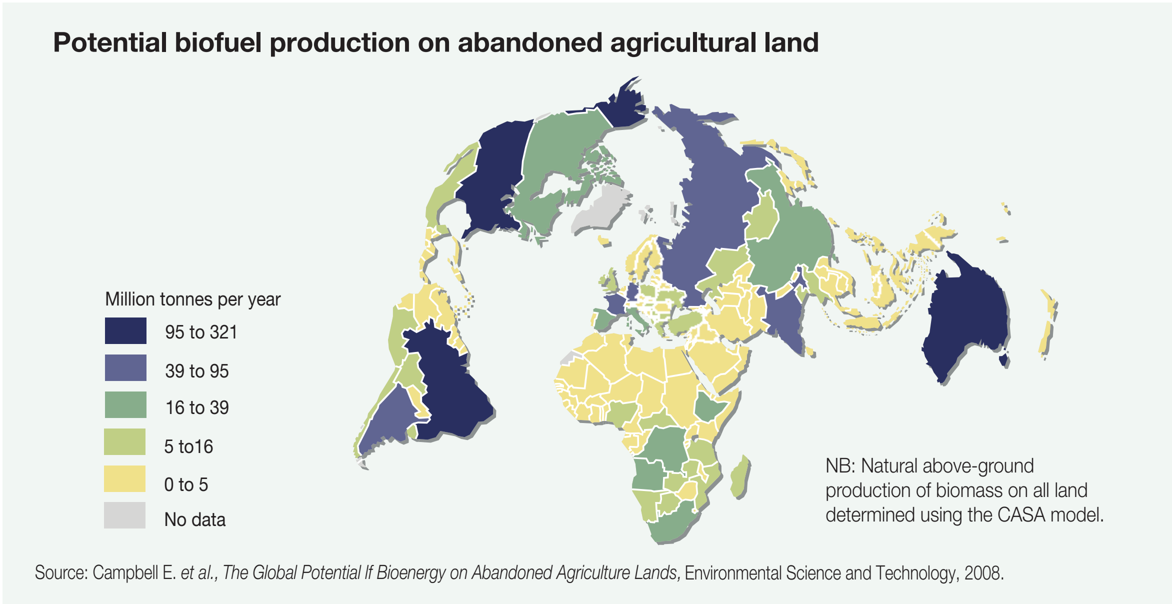
Credit: Nieves Lopez Izquierdo (http://www.grida.no/graphicslib/tag/biofuels)

Figure 5.4: Land required for biofuels by feedstock



Credit: Nieves Lopez Izquierdo (http://www.grida.no/graphicslib/tag/biofuels)

Figure 5.5: Potential biofuel production on abandoned agricultural land



Credit: Nieves Lopez Izquierdo (http://www.grida.no/graphicslib/tag/biofuels)

An internationally agreed upon definition for degraded and marginal lands is necessary to identify sustainable land for biofuel production (UNEP 2009b). According to Gopalakrishnan *et al.* (2011) current definitions of marginal land incorporate a single criterion: agroeconomic profitability. They suggest multiple criteria in classifying marginal land using soil health indicators, current land use and environmental degradation. This definition could further be broadened to incorporate the production history of the land/soil, as well as social and cultural values. There are, nevertheless, database limitations in terms of the quantification and classification of degraded and marginal lands such as the resolution of satellite imagery needed and better quantification of environmental data. Furthermore, when considering economic, soil health and environmental criteria, some land could be considered marginal for conventional crops but not marginal for biofuel crops.

Land use and quality may also change over function, time and space. For example, land that is productive for a purpose in one location may be considered marginal for another use at a different location (Dale *et al.* 2010). Land may also be productive from an environmental standpoint but still be agroeconomically productive; or not agroeconomically productive but still provide ecosystem services and have biodiversity value (Gopalakrishnan *et al.* 2011). Practices that increase land productivity may also result in significant land degradation (see Gopalakirshnan *et al.* 2011). A definition and classification of marginal or degraded land would therefore need to capture the environmental degradation caused by agriculture, and land and water use.

Appropriate cultivation measures could indeed enhance the quality of degraded soil and the vegetation structure, and therefore habitat quality could be enhanced, but outcomes differ between crop and land types used (Tilman *et al.* 2009). For example, soybean cultivation in Argentina exhibits greater soil erosion potential and greater negative effect on soil nutrients than switchgrass, and soil erosion potential is further increased if soybean is cultivated on degraded grassland rather than abandoned cropland (van Dam, 2010). Some fast-growing ligno-cellulosic feedstocks, such as switchgrass and jatropha, that can grow on wide range of soils and climates and may enhance the quality of the soil, have the potential to become invasive (UNEP 2010a). Potential benefits from enhanced productivity and the ability to improve soil need to be weighed against the greater risk of becoming invasive and damaging ecosystems, livelihoods and the economy (UNEP 2010a). The economics of production is also an important issue. By definition some degraded lands are potentially less productive and may require incentives for bringing them under production and/or the use of further inputs, particularly fertilisers and water, each with their own implications for relevant LCAs. More detailed discussion of the topic is provided by Campbell and Doswald (2009), UNEP (2009a) and Stromberg *et al.* (2010).

Two broad issues with using degraded lands for energy crops appear to be receiving limited attention:

1. **Globally, there is competition for degraded land for other uses, in particular food, but also for forestry and as space for urbanization**. At the global scale, this competition for degraded land delivers potentially significant indirect land-use impacts of energy crops grown there; although the Netherlands Agency (2011) and UNEP (2010) consider that the extent of degraded or "unused" land currently existing might make this competition less significant in the short-term.

2. **Regarding GHG emissions, there is currently very limited attention to the option of restoring degraded lands (e.g., through reforestation) *versus* the GHG benefits of growing energy crops**. It is highly probable that restoring natural vegetation and soils on degraded lands might be more beneficial for GHG objectives. In the Strategic Plan for Biodiversity 2011-2020, Aichi Biodiversity Target 15 calls for the restoration of at least 15% of all degraded ecosystems by 2020 (SCBD 2011). There are of course other benefits and drawbacks for each approach that need to be considered.

We conclude that a policy of wholesale use of degraded lands for energy crops as the panacea for solving either indirect land-use impacts or to mitigate climate change could not be supported without further research and analysis involving comprehensive LCAs of all relevant options.

5.2 DIRECT LAND-USE CHANGE AND "HIGH CONSERVATION AREAS"

In theory, land-use change (LUC) is a relatively easily addressed issue (compared to indirect effects) and for this guidelines, or regulations, are well advanced in many forums. Direct LUC occurs when land is converted to biofuel feedstock production from a previous land use, such as natural areas under conservation, wetland, rangeland or agricultural land (UNEP 2009b; Plevin *et al.* 2010). Regulations and guidelines for direct LUC usually involve identification of areas where biofuels are inappropriate, including areas with "high conservation value[12]" (HCV) or similar terminology. For example, the EU Renewable Energy Directive (RED) and Roundtable on Sustainable Biofuels (RSB) (see Box 2.2) set out a number of criteria intended to, among other things, protect valued land, though there are some constraints with this approach. For example, Campbell and Doswald (2009) noted little discussion in the literature of the relationship between the various standards and their varying levels of protection for 'high biodiversity' lands and little consensus on how they should be defined and identified, leaving HCV lands open to interpretation. Even if criteria for HCV lands can be agreed, the problem remains that many countries have limited capacity to undertake the necessary inventories or monitoring. An assessment of the requirements relating to the protection of highly biodiverse grasslands under the RED, for example, revealed a lack of understanding of grassland issues, their biodiversity value and associated land-use change risks. Voluntary schemes relying exclusively on HCV to identify areas of biodiversity value are therefore considered not to be consistent with the requirements of the RED (Bowyer *et al.* 2010).

Land suitability and availability assessments have been widely used to select appropriate lands for biofuel production and optimal yields, whilst minimising social and environmental impacts (UNEP 2009b). These assessments can identify both high-risk areas for land conversion and areas where bioenergy production could be acceptable. Land suitability assessment goes beyond agroeconomic considerations, and analyses competing land uses and land cover. Suitability and availability assessments should consider a range of variables such as temperatures and water balance, topography, soil types, climate change projections, screening of environmentally

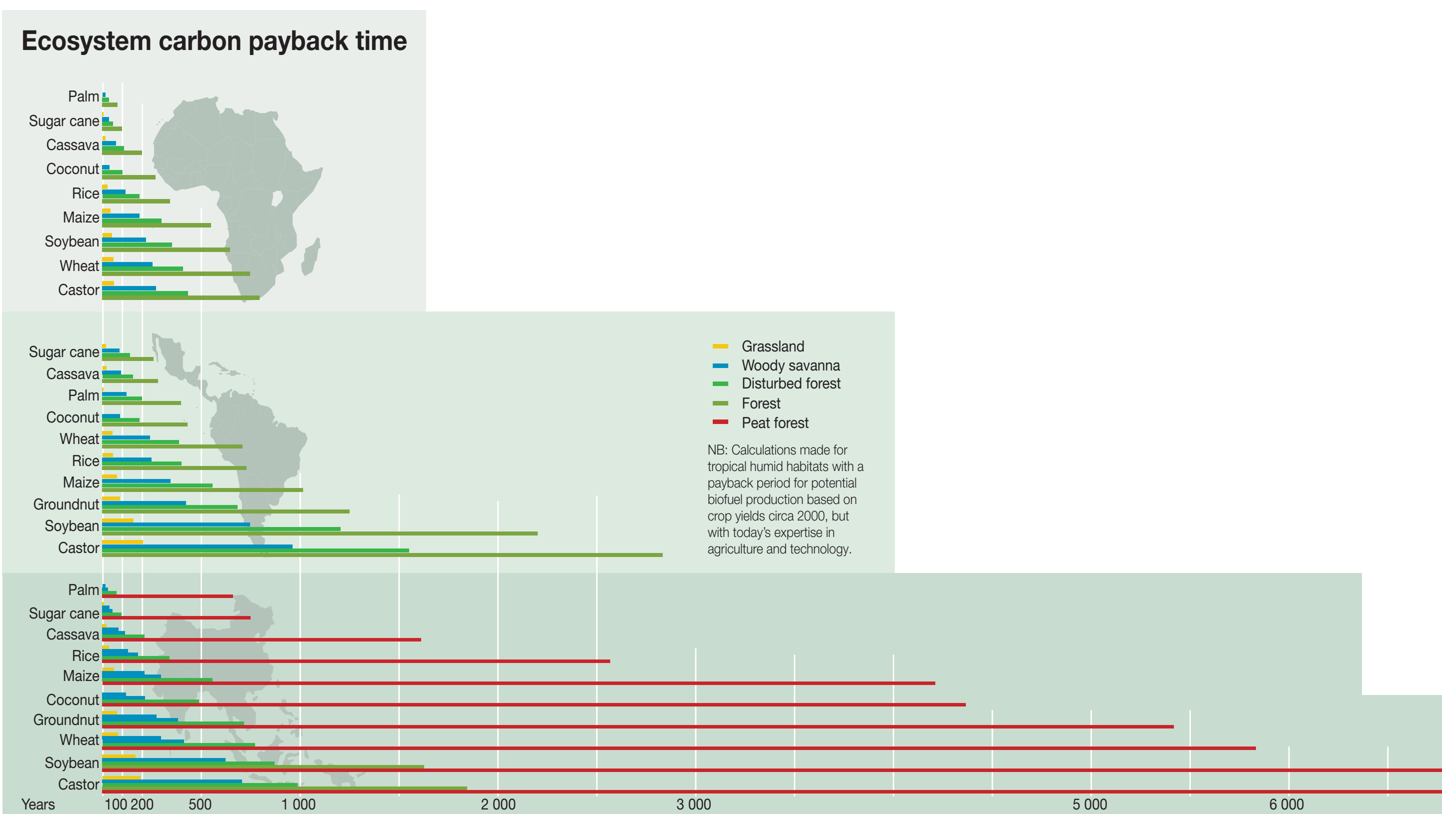
12 "High Conservation Value areas are critical areas in a landscape which need to be appropriately managed in order to maintain or enhance High Conservation Values" – HCV Resource Network (http://www.hcvnetwork.org/site-info/The%20 high-conservation-values-folder/).

sensitive areas, impact on ecosystem services, current land cover and use, conflict zones and land tenure (UNEP/GRID Arendal 2011). Land suitability and availability mapping should also include a bottom-up approach (rather than just mapping), taking into account land tenure and customary rights (UNEP 2009b).

Various freely available tools have been developed by stakeholders to enable identification of HCV areas and to facilitate suitability and availability assessments:

- The **Global HCVF Toolkit** (HCV Resource Network) (available at http://www.hcvnetwork.org/), provides guidance on how to identify, manage and monitor High Conservation Value Forests (HCVFs), and was developed by ProForest for the WWF-Ikea Co-operation on Forest Projects;
- The **World Database on Protected Areas** (available at http://www.wdpa.org/) is the most comprehensive global spatial dataset on marine and terrestrial protected areas; and **Globcover** (available at http://ionia1.esrin.esa.int/) is a land cover database developed by the European Space Agency.
- **Module 1 of the Bioenergy and Food Security Project of the FAO** provides methods for suitability and availability assessment for biofuel feedstock production (available at www.fao.org/bioenergy/foodsecurity/befs).
- **Module 5 on Land Resources of the UN-Energy Bioenergy Decision Support Tool,** provides key drivers and analytical approaches associated with the allocation of land resources for biofuel production (http://www.bioenergydecisiontool.org/about.htm). This tool was developed jointly by the Food and Agricultural Organization of the United Nations (FAO) and the United Nations Environment Programme (UNEP) under the framework of UN-Energy.

Figure 5.6: Ecosystem carbon payback time



Credit: Riccardo Pravettoni, UNEP/GRID Arendal (http://www.grida.no/graphicslib/tag/biofuels)

Bioscore can also help in making land use and policy decisions for biofuels development. Bioscore is a European biodiversity impact assessment tool (available at http://www.bioscore.eu/) used to evaluate possible impacts of changing environmental variables and policy measures on over 1000 species, by taxonomic group and geographic region (Delbaere *et al.* 2009). Bioscore was developed by the European Centre for Nature Conservation, the European Commission and partners. By using BioScore, Louette *et al*. (2010) demonstrated that large-scale expansions of woody biofuel plantations in Europe could have a potential net negative effect on the species set covered, with considerable differences among species groups. Eggers *et al*. (2009) assessed potential land-use changes on habitat size and species composition, resulting from what may happen if the European Union doubled its current biofuel target and what would happen if it abolished its current biofuel target. A doubled biofuels target would most likely result in increased habitat loss and negative effects on species, while abolishing the target would have mainly positive results on biodiversity and associated habitat (results vary spatially and with crop choice) (Eggers *et al*. 2009).

Proposed long-term solutions for direct LUC include reductions in bioenergy feedstock demand through greater efficiency in technologies, end-use and feedstock choices (UNEP 2009b). Biodiversity can also be better protected through sustainable agriculture, reducing agricultural inputs and restoring degraded lands (UNEP 2009b). Enhancement in the efficiency of yields and production of biofuels, rather than expanding onto more land to meet energy demands, has also been suggested (Savage *et al.* 2011; Fairley 2011). In the longer term, comprehensive land-use planning and management systems, incorporating multi-functionality and multi-level planning (global, regional and local) could integrate land use across many sectors, while still providing for biodiversity and ecosystem services. This approach could also support informed decision-making, as well as a cross-sectoral and participatory approach through community involvement and stakeholder consultations. The next step would be calculating trade-offs between the economics of redesigned landscapes and current practices at the field/farm scale to determine more efficient ways of integrating biofuel feedstock production into current land management practices.

BOX 5.2: Key characteristics of iLUC that need to be taken into account by mechanisms that aim to resolve iLUC issues

- *Displacement effects across national borders*: For example, in 2008, 90% of the biofuel used in the UK was derived from overseas feedstock, requiring an estimated 1.4 million hectares of overseas land for its production (JNCC 2009). By 2020, it is projected that demand for imported biofuels would require an additional 4-8 million hectares of land (JNCC 2009);
- *Displacement effects across substituting crops*: For example, if the EU diverts rapeseed oil from food to energy, this could increase vegetable oil imports; and
- *Competition for land between non-substituting crops*: For example, planting more corn and less soy due to high prices and demand could trigger an expansion of soy in other regions (Cornelissen *et al.* 2009; Dehue *et al.* 2009; Dehue *et al.* 2011).
- *Intensification LUC* occurs when more intensive forms of agriculture are used but the total cultivated area remains the same. Intensification iLUC has received far less attention and its impacts can be positive or negative. Intensification can reduce the overall area of land required for cultivation thus potentially avoiding, or even reversing, conversion. However the increased agricultural inputs that this intensification might require, particularly water, fertilisers and other chemicals, can have major GHG implications and other detrimental impacts on biodiversity (e.g. pollution). Further discussion on intensification impacts on water is provided by UNEP/Oeko-Institute/IEA (2011).

Source: Gibbs, H., K., *et al., Carbon payback times for crop-based biofuel expansion in the tropics: the effects of changing yield and technology*, Environmental Research Letters, 2008.

5.3 INDIRECT LAND-USE CHANGE (ILUC)

Indirect land-use change (iLUC) remains a key unresolved biodiversity-related issue with biofuels. Biofuel production requires large areas of land normally dedicated to agricultural production. Land dedicated to agricultural production may then be displaced to other areas to keep up with demand for food and feed (Khanna and Crago 2011; Nuffield Council on Bioethics 2011; UNEP/GRID Arendal 2011). Indirect land-use change (iLUC) occurs when biofuel feedstock production displaces previously productive land (e.g., agricultural land for food production) to other areas, causing deforestation or conversion of natural habitat and potentially negative impacts on carbon stocks and biodiversity (Dehue *et al.* 2011; Cornelissen *et al.* 2009). GHG emissions can be especially substantial when indirect land-use change occurs at the expense of grassland, forest, woodland, peatland and other wetland, which are important carbon sinks (Nuffield Council on Bioethics 2011; SCBD 2009). When iLUC occurs, biofuels are said to create a "carbon debt", where carbon emissions generated from land conversion (or land-use change) must be "paid back" by the CO_2 absorbed by the biofuel crop (Fargione *et al.* 2008; UNEP/GRID Arendal 2011). Therefore, ecosystem payback time is the amount of time required to offset carbon emissions generated by converting land for biofuels. Estimates for this payback period vary from decades to millennia (in the case of peat forest) across different types of biofuels, ecosystems and regions, as well as different modelling assumptions used (UNEP/GRID Arendal 2011) (see Figure 5.6 above).

Serious doubts about the sustainability of biofuels have been raised as a consequence of iLUC. These include significant GHG emissions, as well as social and environmental impacts affecting biodiversity, food security, water quality and land rights (Nuffield Council for Bioethics 2011). Some argue that when GHG emissions from iLUC are accounted for, biofuels offer few benefits in terms of climate change mitigation compared to fossil fuels (Searchinger *et al.* 2008; Fargione *et al.* 2008; Melillo *et al.* 2009; Hertel *et al.* 2010). One study estimates that biofuels expansion is responsible for up to twice as much carbon loss from indirect land-use change than direct land-use change (Melillo *et al.* 2009). The debate on iLUC currently appears to be moving from a scientific to a policy issue. The current scientific consensus is that iLUC effects are real; yet the problem remains as to whether iLUC can be quantified in a way that can support decision-making and regulatory measures that promote sustainability (Mathews and Tan 2009).

Because iLUC is a result of larger macroeconomic market dynamics, establishing links between the potential displacement and biofuel production is difficult to quantify (UNEP 2009a). There is great complexity involved in determining specifically which biofuels crop caused the displacement of productive land, and how much and where iLUC occurred as a consequence (Melillo *et al.* 2009; Yeh and Whitcover 2010; Nuffield Council for Bioethics 2011; Di Lucia *et al.* 2011). Scientists, economists and policy-makers have used models to estimate the iLUC consequences of biofuel policies (Sanchez *et al.* 2010; Yeh and Witcover 2010; Malins 2011). To further complicate calculating emissions caused by iLUC, confounding factors include the increased requirements for land to grow food due to a growing world population, changing diets in response to increasing wealth (e.g., more meat, which requires more land), expanding biofuels and non-food crop production, degradation of agricultural land and urbanization, amongst many other factors. In order to estimate the amount of iLUC due to biofuels, simulation experiments with global economic models are used to separate the effect of biofuels expansion from other causes of land-use change (Lambin and Meyfroidt 2011). The use of crop wastes and residues, multi-cropping, and changes in consumption and yield increases as a response to higher food and feed prices are some of the complexities that are integrated into these models (Lambin and Meyfroidt 2011). Most quantification work has only focussed on GHG emissions from iLUC from liquid biofuel production. Dehue *et al.* (2011) reviewed the various approaches used to quantify iLUC and compare outcomes and underlying assumptions. The study found no clear consensus on the size of the total emissions from LUC or iLUC, due to large ranges of results and differences of methodologies and key assumptions. The study recommends a more comprehensive documentation of assumptions and intermediary results for a better comparison between models, as well as their similarities and differences.

Other aspects of iLUC, especially biodiversity implications, have been poorly addressed. Bertzky *et al.* (2011) provide a review of iLUC with regards to biodiversity impacts concluding, for example, that the direct effects of the EU Renewable Energy Directive (RED) on land use will be small, but indirect effects may be considerable. The areas that will be mostly affected are areas with semi-natural vegetation, whereas plantation areas are projected to increase, with most impacts occurring outside the EU. JNCC (2009) provides similar observations specifically for an assessment of the footprint of bioenergy use in the United Kingdom. The complexities of iLUC make the assessment of iLUC impacts on biodiversity extremely challenging, and have impeded the development of safeguards that might limit the impacts. Nevertheless, these gaps are being increasingly recognized, and although iLUC cannot be entirely avoided or adequately measured, efforts are underway to mitigate iLUC (see examples below).

BOX 5.3: The history of iLUC

Two papers published in the same issue of *Sciencexpress* in 2008, one by Searchinger *et al.* and another by Fargione *et al.*, initiated the on-going debate on the scale and significance of iLUC.

When comparing the life-cycle assessment of both corn and cellulosic ethanol to gasoline, it was found that carbon emissions increased compared to gasoline by 93 and 50 percent respectively, when iLUC was considered (Searchinger *et al.* 2008). Searchinger *et al.* estimated the potential iLUC in response to increases in corn ethanol production in the USA of 56 billion litres above projected levels for the year 2016 (the goal for biofuels set by the USA Congress). They assumed that all the extra corn to fulfil expanding biofuels would be grown in the USA. It was projected that USA agricultural exports would decrease as a result of increased corn ethanol production (corn by 62%, wheat by 31%, soybeans by 28%, pork by 18% and chicken by 12%). Countries that normally import corn from the USA would have to replace their demand with grain, which would require an estimated additional 10.8 million ha of newly planted land, including at the expense of grassland and forest, resulting in calculated emissions of 3.8 billion tons of CO_2 equivalent, due to the iLUC effect of meeting an ethanol production target of 56 billion litres. Searchinger *et al.* estimated that the production of corn bioethanol would increase emissions for 167 years, after which the GHG emissions reductions from the use ethanol would begin to "pay back" the emissions from the carbon released from the land-use change. Searchinger *et al.* also estimate that if corn fields were converted to switchgrass for ethanol production, replacing the corn would still generate emissions from iLUC that would take 52 years to pay back. They argue that using good cropland for biofuels would likely aggravate global warming, and highlight the benefits of using waste products as feedstocks.

Calculating iLUC is controversial and many studies have generated varying results. For example, a study by Hertel *et al.* (2010) estimated that the GHG emissions from USA corn bioethanol were roughly a quarter of that for Searchinger's 30 year estimate, because it factored in market-mediated responses to increasing biofuel production in the USA and accounted for the use of by-products. Considering by-products or co-products can affect and sometimes improve GHG emissions reductions in LCA, and estimations on iLUC (Nuffield Council on Bioethics 2011). However, even Hertel *et al*'s estimate was still large enough to cancel out the beneficial effects of corn ethanol on climate change.

Whether it is through direct or indirect land-use change, clearing land to grow biofuels creates a carbon debt. In Fargione *et al.* (2008), carbon debt is defined as the amount of CO_2 released during the first 50 years of land conversion from natural habitat to produce crop-based biofuels. Crop-based biofuels were found to release 17-420 times more CO_2 than annual GHG emissions reductions from displacing fossil fuels. Fargione *et al.* (2008) also found that biofuels produced on converted land would be much greater GHG emitters than fossil fuels. Oil palm biodiesel grown on converted tropical rain forest would incur a carbon debt that would take an estimated 423 years to repay. Sugarcane ethanol grown on Brazilian cerrado would take approximately 17 years to repay. They suggest biofuels made from waste, perennials or planted on abandoned agricultural land would offer much better GHG emissions reductions and little or no carbon debt (Fargione *et al.* 2008).

i. Proposed solutions to mitigate iLUC

Preventing unwanted direct LUC could in theory eliminate iLUC, or at least help limit or mitigate it. Unwanted effects from iLUC from bioenergy are a by-product of direct LUC from the food and feed sector (Dehue *et al.* 2011). However, because of the international nature of iLUC and competition for land from various sectors, global implementation of integrated land-use planning and monitoring in **all land-based sectors would be necessary for this strategy to be effective**. While LUC can be addressed by certification, all biomass products would have to be certified to prevent iLUC from happening (Dehue *et al.* 2011). Although this measure could be effective in the long term, Dehue *et al.* (2009; 2011) suggest intermediate solutions be implemented in the short- to medium-term that acknowledge the lack of control of the biofuels sector on the sustainability of other biomass-consuming sectors. The small amount of mitigation measures existing for iLUC are not yet fully operational (see examples below). Most focus only on GHG effects of biofuels by incorporating a LCA of feedstock-based biofuel pathways (Dehue *et al.* 2011).

There are currently no standards or criteria that can prevent iLUC from happening. iLUC cannot be entirely avoided but can only be mitigated by standards, guidelines and certifications that can reduce drivers. Bertzky *et al.* (2011) note that sustainability standards and criteria for first generation biofuel crops aim at preventing biofuel production encroaching on areas of importance for biodiversity and ecosystem services. They represent a mechanism to control where conversion for biofuel production will take place in the future. This presents a gap in the sustainability standards: by banning biofuel crops from certain areas, their cultivation on existing agricultural land is encouraged, thereby encouraging food crops or feedstock in the areas that biofuel crops are banned from hence promoting iLUC (Searchinger *et al.* 2008).

Intensification is often cited as a solution to mitigate iLUC impacts. For example, Lapola *et al.* (2010) analysed the impact of biofuels expansion in Brazil at reasonably fine spatial scales. The simulations show that direct land-use changes will have a small impact on carbon emissions because most biofuel plantations would replace rangeland areas. However, indirect land-use changes are potentially significant, with sugarcane ethanol and soybean biodiesel each contributing to nearly half of the projected 121,970 km^2 of indirect deforestation by 2020. This would create a carbon debt that would extend the payback time for sugarcane ethanol by an additional 40 years and for soybean biodiesel by 211 years, when considering carbon emissions from iLUC, if using these biofuels instead of fossil fuels. However, if cattle production is sustainably intensified, with an increase of 0.13 head per hectare in the average livestock density throughout the country, the iLUC caused by biofuels can be avoided (even with soybean as the biodiesel feedstock), while still fulfilling all food and bioenergy demands. Theoretically, a combination of intensification of cattle production and restoration of rangeland into forests could generate potentially greater reductions in iLUC and GHG emissions, than solely using intensification for the purpose of biofuel and food production. However, this may not be feasible from a socioeconomic perspective. **This example illustrates the importance of integrating planning for bio-energy and other production activities, which centre on a more holistic framework of land-use planning (including other relevant inputs onto land such as water and chemicals etc.)**

ii. Integration of iLUC into policy

Because of the lack of clear guidance from the scientific community on the scale and severity of iLUC, there has been a deadlock in terms of regulatory actions. There has been an urgent need to address iLUC in biofuels policies (Di Lucia *et al.* 2012). Scientists continue to claim the need for more research, data and better models. Policy makers continue to refrain from taking decisions due to the lack of clear definitive answers from the scientific community. There may be no ultimate exact results on iLUC due to different assumptions and a certain level of uncertainty, yet there is a range of variable yet valid information that needs to be considered by decision-makers (Di Lucia *et al.* 2012). Science can provide support, monitoring and assessment of policies but it is not a predictive oracle underpinning decision-making (Di Lucia *et al.* 2012).

The consensus on the best ways in which to deal with the iLUC problem have shifted from trying to monitor and directly manage land-use change to pro-active mitigation of iLUC. iLUC cannot be quantified accurately enough to support decision-making but it is possible in the short-term for assessments to identify levels of risk of iLUC and develop policies accordingly by rewarding low-risk strategies and discouraging high-risk ones (Oorschot *et al.* 2010). For example, the Global Bioenergy Partnership (GBEP) indicators (see Box 2.1) provide a great deal of information to guide decision-making to mitigate the risk of iLUC. GBEP's LUC indicator incorporates metrics that identify the proportion of no iLUC risk, low iLUC risk and high iLUC risk feedstock production in a country's bioenergy mix. Their LCA methodology also allows users to calculate emissions from iLUC, if they choose to do so.

iLUC factors have been introduced into USA regulations and are being considered by the EU and some voluntary certification initiatives. An iLUC factor is an estimated amount of GHG emissions caused by iLUC that is attributed to each type to biofuel or biofuel feedstock (Di Lucia *et al.* 2012; RSB 2012a). This is then added to the direct emissions calculated in LCA to obtain total GHG emissions (Di Lucia *et al.* 2012). An iLUC factor will only be a rough estimate as there are modelling uncertainties, which include the choice of model, the set of assumptions and the mix of policy variables. If the iLUC factor is set too high, this may hinder the biofuels industry (Khanna and Crago 2011). At present, it is not possible to assess how realistic the current levels of emissions attributed to iLUC are in these measures. It is also worth reiterating that these measures only, currently, include GHG emissions and no other iLUC factors.

BOX 5.4: An example of economic assessment of biofuels policies

The economic assessment of biofuels policies with regards to sustainable biofuels objectives is an important tool to assist policy development, given that markets, financing and behavioural change by producers are key factors**.** Ernst and Young (2011), for example, explore the four existing policy options being considered by the European Commission to deal with iLUC under the EU Renewable Energy Directive (RED):

1. take no action and continue to monitor;
2. increase the minimum GHG savings threshold for all biofuels;
3. add sustainability requirements for selected biofuels; and
4. Estimate the GHG emissions from iLUC using an "iLUC factor" derived from modelling.

The analysis considered the policy options in relation to their potential positive, uncertain or negative impacts on:

a) encouraging action to mitigate iLUC;
b) improving GHG performance;
c) fulfilling mandates cost-effectively; and
d) improving investor confidence.

All four current policy options, to varying degrees, perform negatively in terms of encouraging practices to mitigate iLUC and three reduce investor confidence. Ernst and Young (2011) propose an alternate fifth policy option, which is to reward feedstock producers for mitigating iLUC with the credit offsetting additional costs of production. They estimate that if 10% of all biofuels used in the EU in 2020 qualified for a 29gCO_2eq/MJ iLUC mitigation credit, financial value of up to $1.6 billion could be created as incentive.

iii. Voluntary tools and project-level approaches

The Roundtable on Sustainable Biofuels (RSB) (http://rsb.epfl.ch; see Box 2.2) created an Indirect Impacts Expert Group to recommend a strategy to be integrated into the standard. RSB recently underwent stakeholder consultations in order to find the best way forward to deal with iLUC (RSB Secretariat 2012). They presented the following options, which could be applied in combination:

- Option 0: take no action. The RSB does not yet address iLUC impacts and therefore the standard would remain unchanged. The rationale is that fossil fuels also have indirect impacts that would outweigh the negative indirect impacts of biofuels;

- Option 1: incorporate a voluntary "low indirect impact risk" module to the existing RSB standard to certify certain projects. This would incorporate some the solutions provided below by the RCA methodology;
- Option 2: adopt criteria and requirements to implement best practices to minimize iLUC that are mandatory for all operators certified by RSB;
- Option 3: applying an iLUC factor to GHG LCA calculations on specific feedstocks. However, by applying the iLUC factor, many operators may not be able to attain the minimum 50% GHG emissions reduction threshold, although such an outcome would simply illustrate that biofuels were not actually meeting GHG reduction targets;
- Option 4: undertake a regional assessment of potential risk of iLUC based indicators that measure trends such as exports of commodities, land-use governance, yield trends etc..;
- Option 5 (as an alternative to option 2): a biofuels operator would contribute time, technical help or financial resources to a fund to help another party apply best management practices.

The majority of respondents to the stakeholder assessment suggested a combination of option 1 and 2, where option 1 would be implemented in the short term, followed by option 2. The majority of the respondents preferring option 1 and 2 were academics and researchers, as well the producers who chose to address iLUC. NGOs tended to prefer option 3. Producers, in general, were more inclined towards option 0 (RSB 2012b).

The Responsible Cultivation Area (RCA) approach offers practical and field tested methods to reduce the risk of iLUC effects (Dehue *et al.* 2009). Ecofys launched the RCA methodology in 2010, which was further developed by Conservation International and WWF International. RCA has been pilot tested in Brazil and Indonesia. The most promising results of the three pilot locations were in the state of Pará, Brazil (Conservation International 2010). The pilot test demonstrated that the RCA methodology is effective in identifying areas with minimal social and environmental value for oil palm production that had a low risk of iLUC. The approach has potential to be incorporated into policy and voluntary standards. There is also interest from the private sector to incorporate into RCA into land use planning.

At the project level, the RCA methodology proposed four main solutions to expand biomass usage for biofuels that do not cause iLUC (Dehue *et al.* 2009):

1. Biomass production on "unused land" ("land that does not provide provisioning services"). This leads to direct LUC, which can be controlled by certification, unlike iLUC, which is largely uncontrollable. However, there are many uncertainties in this approach, as explained in the section on degraded lands above;
2. Introducing energy crop cultivation without displacing the original land use through increased land productivity/yield increases or integration models (such as the integration of sugarcane and cattle, described above), especially in developing countries;
3. Bioenergy production from residues/waste biomass;
4. Bioenergy production from aquatic biomass. (But see comments in Section 1 noting this transfers iLUC impacts from land to wetlands).

The RCA approach focuses on the first two mitigation options, which are the first two modules of the RCA methodology: Module 1: Distinguishing bioenergy feedstock production with a low risk of indirect effects. Module II: Identification of Responsible Cultivation Areas.

iv. Regulatory approaches

Estimates of iLUC emissions have been integrated using "ILUC factors" in the United States of America federal Renewable Fuel Standard (RFS2) by the Environmental Protection Agency (EPA) and in California's Low Carbon

Fuel Standard (LCFS) by the California Air Resources Board, both of which require that direct and indirect LUC be integrated into LCAs (Yeh and Witcover 2010). The California Low-Carbon Fuel Standard (LCFS) uses "carbon intensity" (CI) reference values for each feedstock, which includes an iLUC factor. The CI rates the GHG emissions performance of various biofuels and is expressed in terms of grams of CO_2 equivalent per mega-Joule (gCO_2e/MJ) (Yeh and Witcover 2010; CARB Advisory Panel 2011). The LCFS's target is to reduce carbon intensity of transportation fuels by 10% by 2020. The lower the CI for a feedstock and production pathway, the more carbon credits it can generate (Yeh and Witcover 2010).

There are various models used by regulatory agencies; yet, there is no single model that can generate a single iLUC factor that can be used for all policy decisions (Yeh and Witcover 2010). Differing models, inconsistency in data and different assumptions used create difficulties in comparison of results, inconsistencies between regulations and prices for low carbon fuels. GHG accounting methods and assumption methods can be similar; yet CI values are expected to vary between jurisdictions due to local influences on the inputs to the fuel production chain (CARB Advisory Panel 2011).

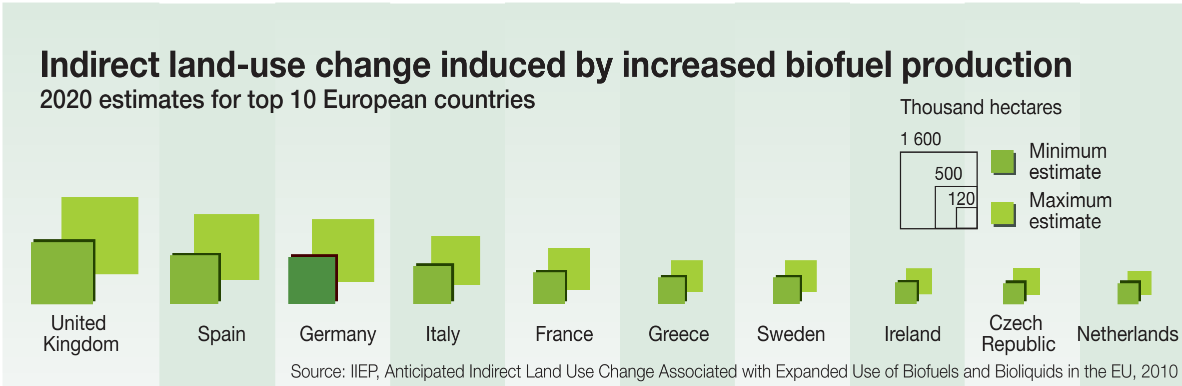
The California LCFS uses a combination of models to calculate CI values:

- The GREET (Greenhouse Gases regulated Emissions and Energy Use in Transportation) model used for LCAs includes more than 100 fuel production pathways from various biofuels feedstocks. The model has been adapted to regional needs in California (CA-GREET).
- The GTAP (Global Trade Analysis Project) is a computable general equilibrium (CGE) model used for land use assessment. This type of model is designed to find equilibrium: If a change is introduced into the model, a number of related variables will also change. For example, if increased biofuel demand is introduced, land use will change and associated prices will change until an economy-wide equilibrium is attained (CARB Advisory Panel 2011).
- The Environmental Protection Agency (EPA) uses the FAPRI/FASOM (Food and Agricultural Policy Research Institute/Forest and Agricultural Sector Optimization Models) for the US RFS2 (federal); however, unlike the LCFS, the direct and indirect CI values are combined for an overall value and it is not possible to distinguish the iLUC value separately (Sanchez *et al.* 2012).

Whether and how to integrate iLUC into the EU Renewable Energy Directive (RED) and the UK Renewable Transport Fuels Obligation (RTFO) is still under review. The EU have not reached consensus on how to mitigate iLUC but agree that it needs to be addressed or it is unlikely to achieve significant emissions reductions from EU biofuel policy. Furthermore, it is unlikely that the EU will have the necessary available land to fulfil its biofuel mandates, creating a spill-over into other countries or regions (UNEP/GRID Arendal 2011).

The EU has been using the IFPRI MIRAGE economic model as one of the best available method to resolve assessment iLUC in the EU RED (Malins 2011). This model has been used to estimate both the land use change and the carbon emissions due to the EU RED, as well as the emissions related to increasing demand for biofuels for different feedstocks (i.e. iLUC factors) (Malins 2011). Figure 5.7 provides estimates of iLUC induced by biofuel production for the top 10 European producer countries in 2020 (a variety of economic models were used to generate the data for this figure). Currently, the EU RED provides a bonus for biofuels made from bioenergy feedstocks that have not displaced food production and have been cultivated on severely degraded or heavily contaminated land, provided that there is proof of an increase in carbon stocks and a decrease in erosion, and that soil contamination is reduced. For example, the EU RED incorporates two sets of sustainability criteria (Article 17), one for GHG emissions reductions and another for land-use requirements (but they do not consider iLUC).

Figure 5.7: Indirect land-use change induced by increased biofuel production



Credit: Riccardo Pravettoni, UNEP/GRID-Arendal (http://www.grida.no/graphicslib/tag/biofuels)

v. Conclusion (iLUC)

ILUC is a global market-driven phenomenon that cannot be directly observed and attributed to specific biofuels. Estimates of iLUC have been modelled based on policy assumptions, economic behaviour and international trade. The magnitude of GHG emissions caused by iLUC vary for different types of feedstocks, ecosystems and regions, as well as different modelling assumptions used. The ideal way to regulate iLUC could be by protecting global carbon stocks as part of internationally agreed policies on climate change; but this would only be feasible in the longer term, and mitigation options have been the focus for the short- to medium- term. If government policies promote better biofuels that have potential for greater GHG emissions reductions compared to fossil fuels, iLUC could be minimized. These might include some biofuels produced from waste biomass, high-yielding non-food grasses, algae and municipal waste. Land use policies that prevent the conversion of natural forest and ensure soil carbon is maintained or enhanced can also be beneficial provided there are no significant leakage effects into other areas. Sustainability standards and land use management policies need to be included in regions where iLUC would occur and provide incentives so that natural habitat is not converted to biofuels plantations. Consumers of biofuels should also be willing to pay a premium price for products that are certified sustainable by credible sustainability standards. Another option to consider is the use of other renewable alternatives (e.g., solar power) that do not require as much land as biofuels and would not compete with other land uses.

Sustainable intensification[13] of global agriculture and land use offers some opportunities to address a broader range of iLUC impacts. Efforts to mitigate iLUC are currently focused on GHG emissions, whereas other significant social and environmental impacts also need to also be addressed affecting biodiversity, water quality, food prices and supply, land tenure and livelihoods of local communities. If sustainable productivity gains are realised, for *both* biofuels and other land (and other resource) use activities, there is potential to minimise, and even possibly reverse, the impacts of biofuels on biodiversity. Some countries are making good progress with this approach.

In essence, the key need is for sustainable land and other resource use planning under multiple demands. Under the Convention on Biological Diversity (CBD), this broader context is that biofuels be considered, together with other drivers and pressures, under the Strategic Plan for Biodiversity (2011-2020) and achieving the Aichi Biodiversity Targets collectively; in particular targets 3, 4, 7, 8, 11, 14 and 15 (SCBD 2011). This requires an ability to assess multiple drivers, and their interactions amongst multiple targets and objectives, and to generate practical policy relevant guidance. This encompasses, inter alia, effective Strategic Environmental Assessment, or related approaches, and, in particular, requires a responsive policy and management framework. This issue has not been comprehensively explored, and to do so extends well beyond the issue of biofuels alone. However, assessing gaps in tools and approaches within this broader context is a primary requirement.

13 see Royal Society 2009; Nuffield Council on Bioethics 2011

6. TARGETS, SUBSIDIES, TARIFFS AND OTHER ECONOMIC MEASURES

The development of biofuels has been largely driven by governments through subsidies, which have come under scrutiny as being insufficiently supported by science (e.g., UNEP 2009a). Subsidies for biofuels have increased dramatically in the last decade. The International Energy Agency (IEA) estimated the global biofuels subsidies to be approximately US$14 billion in 2007, increasing to US$20 billion in 2009 and US$22 billion in 2010 (IEA 2009; GSI 2011; IEA (2011b). The USA and the EU are the top supporters of biofuels globally, with estimates of about US$8 billion each in 2009, according to the limited information available (GSI 2011). In addition, the widespread subsidies provided to energy, for example incentives for renewable energy sources, can also indirectly translate into subsidies for biofuels. Brazil abolished production quotas and ethanol subsidies in 1990, and sugar and ethanol prices were left to the free market, which brought along considerable efficiency gains (Moraes 2011).

There is limited reporting and lack of clarity by governments on the magnitude of support for biofuels. The Global Subsidies Initiative (GSI) (2011) study reports significant information gaps and inconsistent monitoring and reporting for biofuels subsidies (see http://www.globalsubsidies.org/research/biofuel-subsidies for many detailed studies on national subsidies for biofuels by the GSI). Adequate reporting and evaluations of the effectiveness of subsidies could better determine when they are found to act contrary to the aims of sustainable development, so that governments can subsequently reform or eliminate them (GSI 2011). In the case of the EU, the GSI (2010) highlights the urgent need for yearly, mandatory and standardized reporting of Member States to the European Commission on their biofuel policies. There is also a need for strategic environmental assessments (SEA) and economic assessments on policies and subsidies with regards to sustainable biofuels objectives.

BOX 6.1: What are subsidies?

"Subsidy" can be referred to as a direct transfer of funds from a government to the private sector (GSI 2012). However in policy circles, subsidy refers to any preferential treatment that a government provides to consumers or producers (OECD 1996; GSI 2012). Therefore consumption mandates can also be considered a subsidy (IEA 2011b; GSI 2012).

Subsidies are used to support a product that supplies a public good that a market fails to create. Subsidies are usually a temporary measure to support maturation of new technologies, to eventually reduce costs and increase competitiveness over time (OECD 1996; GSI 2012).

For oil importing countries, subsidies to domestically produced biofuels are driven by a need to reduce foreign trade deficits and save foreign currency earnings (GSI 2012). Subsidies in one country can affect the biofuel industry in another. For example, biofuels support in developed countries has contributed to export-oriented expansion in many developing countries (see Section 7: Local socio-economic and environmental impacts of biofuel feedstock production).

Since there has been billions of dollars already invested in biofuels and biofuel infrastructure, there is a strong incentive to continue, although some of the infrastructure can be converted to support more advanced fuels and processing methods (GSI 2012). There is also few other alternatives to biofuels for liquid transportation fuels, but biofuels subsidies could still also go to other sustainable innovations such as hybrid, electric and hydrogen cars.

Subsidies and tariffs tend not to take into account whether a biofuel is sustainable, and the connection between a biofuel's sustainability and cost can be obscured (Robbins 2011). Biofuels to-date have performed poorly, and in some cases negatively, in terms of climate change mitigation, and costs are exceedingly high. According to the Organisation for Economic Co-operation and Development (OECD) (quoted by UNEP 2009a), subsidies in the USA, Canada and the EU represent between US$960 -1,700 per tonne of CO_2eq avoided in those countries, far exceeding the carbon value at European and USA carbon markets. The Gallagher Review (Gallagher 2008) highlighted considerable uncertainties as to the greenhouse-gas reduction benefits of biofuels.

Many organizations have called upon the G-20 and other governments to revise their biofuels subsidies in light of questionable GHG emissions reductions, the food vs. fuel debate, and other socio-economic issues (GSI 2012). Policy makers and the general public continue to remain poorly aware of the scientific research citing negative social and environmental impacts of biofuels (GSI 2012). It has been said that "the policy on biofuels is currently running ahead of science" (John Ashton, UK Foreign Secretary's Special Representative on Climate Change, quoted in Roger 2007). Furthermore, the GHG emissions from indirect land-use change are still characterised by uncertainty and the technical details are poorly understood by the public and policy makers (GSI 2012). Decision-makers and stakeholders should also set realistic targets based on the planet's capacity to generate additional biomass without jeopardizing ecosystems and their services (EEA Scientific Committee 2011).

Specific taxes and subsidies that directly target environmental, energy and agricultural policy goals are a more effective and less expensive than biofuels subsidies (De Gorter and Just 2010). Rather than subsidizing biofuels, fossil fuels should be restricted with pollution and carbon taxes or a cap-and-trade system. Carbon offsets under a cap and trade scheme (now under the Kyoto Protocol) could be offered to biofuels and they could be taxed or subsidized depending on their performance in terms of GHG emissions reductions. However, some caution needs to be taken with "carbon taxes". These may in themselves be an appropriate means of incentivising moves towards carbon neutral economies, but care needs to be taken that they apply to emissions from all relevant sources, not just fossil fuels. Wise *et al*. (2009), for example, compare global land use patterns under three different scenarios: a) business as usual; b) a global carbon tax applied to all carbon dioxide emissions including from land-use change, which favours forest expansion; and, c) incentives that apply to carbon dioxide emissions from fossil fuels and industrial emissions only, without considering land-use change. The latter has dramatic implications for increases in land use for biofuels resulting in significant loss of natural land cover (particularly unmanaged forest), and therefore probably also a significant increase in GHG emissions. This study was included in the Third Global Biodiversity Outlook (SCBD 2010, page 77). It is critical that land-use needs to be taken into account when designing policies to combat climate change (SCBD 2010).

Therefore it is important to consider how biofuels policies interact, rather than studying them in isolation. Most countries use several biofuel policies in concert, and certain combinations of biofuel policies can be contradictory (De Gorter and Just 2010). Adverse interactions between policies can occur when adding subsidies to mandates, or when adding biofuel policies to farm subsidy programmes. Benefits from biofuel policies can be offset by inefficiencies of tariffs, production subsidies and sustainability standards. In their analysis, De Gorter and Just find that mandates are clearly superior to all other policies, and that no biofuel policies complemented each other; they either cannibalized each other or had no effect. The blending quota is the policy with the largest impact on biofuel production globally because it provides a huge stimulus to biofuel demand (Robbins 2011).

Benefits from certain biofuels policies can be offset by inefficiencies of import barriers such as tariffs (de Gorter and Just 2010). Promoting domestic biofuels and maintaining barriers to cheaper imports through tariffs can also lead to global inequities, depriving developing countries of opportunities to participate in new markets (GIS 2007; Harmer 2009). Moreover, once in place, trade-distorting subsidies are difficult to reform. The interaction between trade rules and biofuel subsidies can also cause tensions amongst the major producers of biofuels, and often does not allow imports of cheaper and more sustainably produced biofuels. For example, Brazil disputes a USA ethanol tariff, at 54-cents per gallon, as it prevents Brazil from selling its unsubsidized and more sustainably produced ethanol to the USA (Harmer 2009). Still, certain Caribbean countries under the Caribbean Basin Initiative can export a certain quota of ethanol to the USA tariff-free. Most of these Caribbean countries do not produce ethanol themselves but buy it from Brazil and dehydrate it so that it meets the USA requirement that products qualifying under the tariff quota be "substantially transformed" if they do not originate from the countries themselves (GSI 2007). The EU also imposes high tariffs on Brazilian ethanol: a study by the International Food Policy Institute (2011) concluded that opening biofuel trade in the EU would further improve the emission reduction performance of the EU's biofuels policy mainly because there would be more sustainable ethanol imports from Brazil. If African countries can bring up their agricultural yields, the increased demand for ethanol could be met by African countries if global trade were freed from the tariffs and subsidies imposed by the USA and EU. It is recommended by GSI (2010) that all tariffs on biofuels be abolished (except anti-dumping measures on USA biodiesel in the case of the EU) as they are an undesired form of protectionism from more cheaply produced ethanol, mainly from Brazil. For many countries, the reality is that a significant portion of biofuels and feedstocks will have to be imported.

The Global Subsidy Initiative (GSI 2012) recommend the following to governments:

- Raise the political profile of evidence-based economic, environmental and social costs and benefits of biofuels.
- Report annually the value of subsidies granted to biofuel consumers and producers in a detailed and consistent manner.
- Abstain from introducing new forms of government support to conventional biofuels.
- In the short term, replace the rigid biofuel production or consumption mandates and targets with more flexible arrangements .
- In the middle term, establish and implement a plan for removing national policies that support consumption or production of biofuels that a) compete with food uses for the same feedstock crops and b) have negative impacts on the environment.
- Continue support for the development of infrastructure that allows for more flexibility in the use of biofuels.

6.1 INCENTIVISING RESEARCH AND DEVELOPMENT

Biofuels research and development can deliver breakthroughs applicable across many sectors of the economy (GSI 2010). It can be said that subsidies towards research and development have a great potential to deliver a public good. Less beneficial are subsidies that only target one sector (e.g., demonstration plants). Perhaps allowing private investors to choose their project of interest, through research and development tax credits, is a more effective method to promote progress in the right direction. It has also been suggested that governments should encourage innovation and competition in the marketplace to find the best solutions regarding projects targeting GHG emissions (GSI 2010). The IEA (2010) estimates that direct government spending on research and development for new biofuels are over US$1billion in the USA, US$430 million in Canada and US$12 million in Australia.

A clear pattern across countries is an increasing amount of funding towards second-generation biofuels, especially cellulosic ethanol, a better alternative to first generation biofuels. The USA renewable Fuels Standard (US RFS2) mandates 60 billion litres of cellulosic ethanol by 2022. The EU's sustainability criteria involve GHG emissions standards that grow more rigorous over time, which incentivises the development of biofuels with lower life-cycle emissions (GSI 2012). Another example is the Danish government which funded 8.5 billion Euros from 2007-2009, for pilot projects involving the use of biodiesel in "fleets" of vehicles; and the Finnish Funding Agency for Technology and Innovation's (Tekes) program BioRefine has a budget of 137 million Euros for five years dedicated to the development of second generation biofuels (GSI 2010). In Canada, the NexGen Biofuels CAD$500 million fund has been providing interest-free loans since 2007, for large-scale demonstration facilities producing second generation biofuels (GSI 2009).

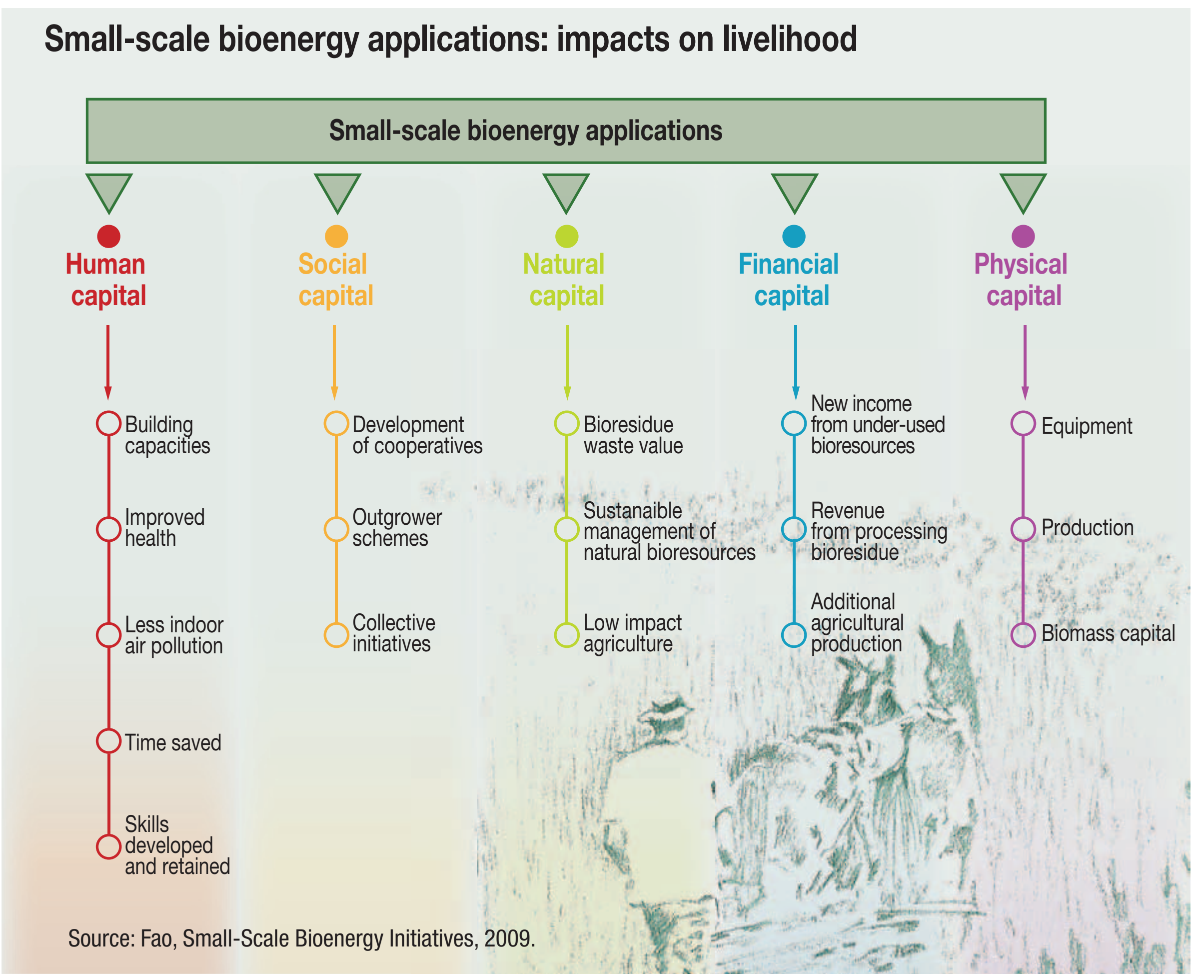
Incentives for research and development should encourage biofuels that require less land and resources, avoid environmental and societal harms, and reduce GHG emissions (Nuffield Council on Bioethics 2011). Technological development must prioritize optimal resource use and allocation, minimising waste and inefficiencies and increasing the biofuels industry's economic efficiency (UNEP/GRID Arendal 2011). The European Energy

Agency Scientific Committee (2011) recommends that policies encourage biofuel production from by-products, wastes and residues that reduce GHG emissions and promote integrated production of biomass without displacing ecosystem services, such as food and fibre production. An important knowledge gap may be the relative investments in solutions addressing biofuels sustainability constraints, relative to those supporting known inefficient, and often detrimental, practices (including perverse incentives that support them). Diverse biofuels approaches encourage efficiency and innovation, but incentives need to support progress in the right direction and not reward practice in the wrong direction. This important issue requires further assessment.

7. LOCAL SOCIO-ECONOMIC AND ENVIRONMENTAL IMPACTS OF BIOFUEL FEEDSTOCK PRODUCTION

Expansion of feedstock production for biofuels has occurred mostly in developing countries of the global south: in Asia, Africa and Latin America. These developing countries largely welcomed these new investments hoping that biofuels would stimulate economic development in rural areas, increase employment, provide new knowledge and income for farmers, and integrate smallholders into the biofuels market (UNEP 2010b; Nuffield Council on Bioethics 2011; German *et al.* 2011a). Biofuels also have the potential of providing cheap renewable energy. This is of particular importance to developing countries where there is limited access to affordable energy (UNEP 2012a). Forty per cent of the world's population and 80% of the population of sub-Saharan Africa rely on traditional biomass as a primary energy source, such as wood, charcoal or dung for cooking and heating: However, these sources are known to cause respiratory diseases with an estimated 1.6 million related deaths a year (GNESD, 2011). Traditional biomass is often obtained through unsustainable exploitation of forest resources (UNEP 2012a). It also significantly contributes to greenhouse gas emissions and can be energetically inefficient compared to modern bioenergy. Modern bioenergy, such as green charcoal, straight vegetable oil (SVO), bioethanol, biogas and waste residues, amongst other renewable energy options, could greatly improve economic and social development (UNEP 2012a). Figure 7.1 below summarizes the potential positive social impacts small-scale biofuel production can have on local communities.

Figure 7.1: Small-scale bioenergy applications: impacts on livelihood



Credit: Nieves Lopez Izquierdo (http://www.grida.no/graphicslib/tag/biofuels)

Energy security, environmental protection and economic development are commonly cited reasons for the expansion of biofuel production in the last decade. This expansion has been driven by biofuels targets and blending mandates of countries favouring the use of biofuels. This may create an artificial market where biofuel producers are incentivized to scale up their production very rapidly, with some setting up large-scale production in countries with lax regulations (Nuffield Council on Bioethics 2011). This can lead to human rights issues in developing countries: for example, the EU's biofuel targets have stimulated oil palm production in Malaysia and Indonesia where large-scale plantations have been accused of outcompeting smallholders (Nuffield Council on Bioethics 2011). Similarly, some African countries such as Ethiopia are now investing in large-scale Jatropha production for biodiesel based on targets, and they may be vulnerable to changing demand if policies change (Nuffield Council on Bioethics 2011). Consideration of human rights and socio-economic impacts of biofuels has been incorporated into voluntary certification standards, such as the Roundtable on Sustainable Biofuels (RSB) (see Box: 2.2) and the Global Bioenergy Partnership's (GBEP) (see Box: 2.1) indicators for sustainable energy; and a limited number of tools, such as the UN-Bioenergy Support Tool (Module 6: People and Processes). It is easier for major biofuel consumer countries to implement and enforce national policies than international ones. For example, the EU Renewable Energy Directive (RED) and the approved voluntary schemes are considered to have weak coverage of offshore social sustainability issues (German and Schoneveld 2011).

Developing countries of the global south (Asia, Africa and Latin America) hold 75–95% of total available and agro-ecologically suitable land (Schoneveld 2011)**.** Large tracts of rural and forested land can be acquired at lower economic and opportunity costs, and regulations are more lax in some developing countries (Schoneveld 2011; German *et al.* 2011a; Nuffield Council on Bioethics 2011). Most suitable land in these regions is either classified as agricultural land, forested land or land under competing uses (Schoneveld 2011). Deforestation and conversion of agricultural land is a greater risk in large-scale industrial biofuels development. This can lead to loss of ecosystem services, threaten food security and undermine rural development. Many of these countries in the global south are more vulnerable to climate change and this is compounded by deforestation and land-use change from biofuel development (Schoneveld 2011).

Most of the concerns about the negative effects of biofuels have been with regard to the large industrial-scale plantations, which have often negatively affected rural livelihoods. Both smallholder feedstock production and large-scale plantations exist in developing countries. Yet, market conditions, government policies and fiscal incentives tend to favour industrial or large-scale plantations, and there is limited support for smallholder market entry in many countries (German *et al.* 2011b). The promise of economic development in the global south through the growth of biofuel feedstocks has led many governments to provide fiscal incentives to attract investors and facilitate access to land (see references in review by German *et al.* 2011b). Large-scale biofuels plantations have impacted food security and food prices, the environment, the rights of farmers, farm workers, and landholders in some developing countries, as well as many problems related to environmental protection (Buyx and Tait 2011; German *et al.* 2011a; Nuffield Council on Bioethics 2011). Furthermore, agriculture already uses half of available water resources in many developing countries, where water can be scarce and there is increased vulnerability to climate change (FAO 2010). Most feedstocks are under intense management where heavy use of agro-chemicals and fertilisers pollute water, deteriorate human health and ecosystems, reduce agricultural productivity and affect food security (FAO 2010).

Three-quarters of the rural poor in developing countries depend on agriculture, but many also heavily rely on natural resources (FAO 2010). This often leads to the natural resources being used unsustainably due to poverty and food insecurity, feeding into the vicious cycle of poverty and degradation of natural resources (FAO 2010). Competition between the biofuels sector and resources used for food production and ecosystem services also threatens food security and local livelihoods (FAO 2010). There is limited information and data on the socio-economic impacts of biofuels on local livelihoods. However, there have been reports from NGOs and research organizations that have flagged biofuels as being harmful to the environment and local communities (e.g., Friends of the Earth 2010a; 2010b; Forest Peoples Programme and Sawit Watch 2010; Global Forest Coalition 2011).

Risks related to biofuels projects must be proactively managed to promote social and economic development in developing countries. German *et al.* (2011b) found a gradient of costs and benefits in in their review of case studies on biofuels development in 12 landscapes within 6 countries of the global south: Brazil, Ghana, Indonesia, Malaysia, Mexico and Zambia. In their findings, direct land use change (LUC) and indirect land-use change (iLUC) (see Section 5: Land Use) were observed in both industrial and smallholder plantations. In smallholder plantations, feedstock cultivation displaced permanent agricultural land, fallow and mature forest. Industrial-scale plantations were associated with high levels of deforestation (13 - 99% of the area used for feedstock production was deforested), with the highest in oil palm plantations in Indonesia. The case study in Mato Grosso (Brazil) had the lowest levels of deforestation and this is likely due to effective governance: strict regulations (1964 Forest Code) on forest conversion, the use of satellite imagery to monitor compliance, enforcement with environmental police, greater involvement of prosecutors and financial incentives to enhance compliance. There is also a 2006 Soy Moratorium on soybeans grown in newly deforested areas signed by almost all soybean buyers that has minimized direct LUC (Andrade and Miccolis 2011).

7.1 FOOD SECURITY

Biofuels have been criticized for competing directly and indirectly with food production, driving up food prices and threatening food security of vulnerable countries and populations (the "food vs. fuel" debate) (FAO 2008b; Gallagher 2008; Gasparatos *et al.* 2011; German *et al.* 2011a)**.** Many developing countries are net food importers, such as in the Sahel region, and are highly affected by high food and biofuel prices (FAO 2002a). The poor are more affected by increases in the price of food because they spend a higher percentage of the earnings on food (FAO 2008b; FAO 2010). The Gallagher Review (2008), an independent review prepared by the UK government on the indirect effects of biofuels, found that increasing biofuel production was increasing the price of food and harming vulnerable countries and populations. It was generally agreed that biofuel production contributed to high food prices but there was little consensus on the extent of the impact (Gallagher 2008; Nuffield Council on Bioethics 2011). Nevertheless, biofuels, and in particular USA corn ethanol, appears to have been a contributing factor to the increase in food prices, although there are several other factors to blame (Nuffield Council on Bioethics 2011). For example, the 2012 droughts in the USA have significantly reduced corn production prompting very public calls for the USA to re-assess its biofuels policies, because of implications for food prices, even if temporarily[14].

Degraded and marginal lands very often support crucial livelihood functions for the most vulnerable people who depend on these lands for subsistence (Rossi and Lambrou 2008, Borras *et* al. 2010; German *et al.* 2011a). In efforts not to jeopardize food security in sub-Saharan Africa and Southeast Asia, biofuels expansion has occurred at the expense of forest, woodlands and "degraded" or "marginal" lands (Schoneveld *et al.* 2011). These so-called degraded or marginal lands, assumed to be abandoned and unproductive, are often woodlands and secondary forests, which producer countries and governments often seek out in efforts not to compete with food production. This avoids issues related to land appropriation and settlement, and investors can capitalize on timber revenues (see refs in German *et al.* 2011b). In some of the case studies reviewed by German *et al.* 2011b, investors reported that it was not possible to profitably grow feedstocks on truly degraded lands. They report difficulties in targeting truly degraded lands (rather than secondary forests) and getting producers to focus on these areas. This undermines the climate change mitigation value of secondary forests and woodlands, which are carbon rich and provide a range of uses that are of value to local communities such as food, income and ecosystem services (see references in German *et al*. 2011b). These degraded and marginal lands very often support crucial livelihood functions for the most vulnerable people who depend on these lands for subsistence (Rossi and Lambrou 2008, Borras *et al.* 2010; German *et al.* 2011a).

14 BBC News, 10 August 2012, "US biofuel production should be suspended, UN says", available at http://www.bbc.co.uk/news/business-19206199

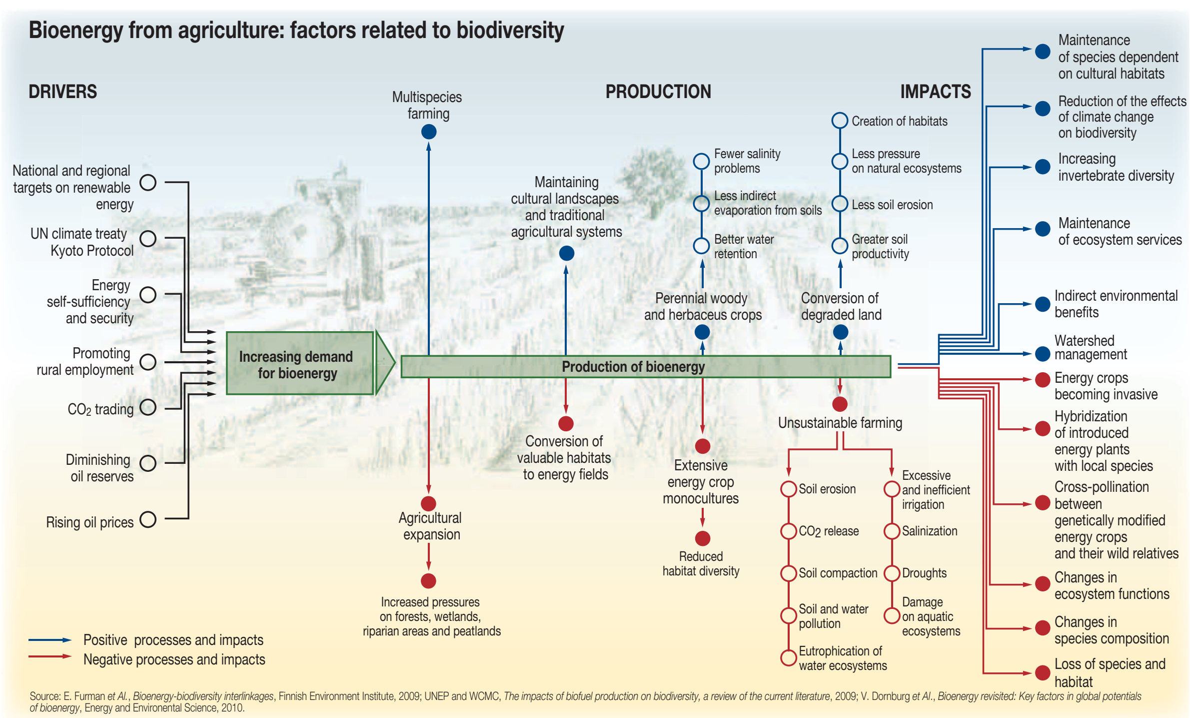
7.2 ECOSYSTEM SERVICES, BIODIVERSITY AND HUMAN RIGHTS

There are many interrelations between the social and ecological systems that support biofuel production. Ecosystem services contribute to local livelihoods and economic development, and are essential for the achievement of the Millennium Development Goals, including poverty reduction (SCBD 2011). Biofuels can provide certain ecosystem services (e.g., fuel, climate regulation, and erosion control) but also compromise other ecosystem services (e.g., food, water) (Gasparatos *et al.* 2011). Figure 7.2 summarizes the major linkages between biofuel production and impacts on the environment and biodiversity. A major knowledge gap identified was the lack of literature linking biofuels, other ecosystem services and human well-being (Gasparatos *et al.* 2011).

The concept of ecosystem services can offer explanatory power to assist policy makers to identify trade-offs in biofuel production (Gasparatos *et al.* 2011). The concept of ecosystem services could facilitate coordinated action for development and enforcement of biofuel sustainability. Gasparatos *et al.* (2011) provide a critical review of drivers, impacts and trade-offs of biofuel production using the concept of ecosystem services and the Millennium Ecosystem Assessment (2005) framework. The authors also cite a lack of consistent language on the diverse trade-offs with biofuels that could better frame the biofuel debate, and lack of tools and toolkits for assessing the sustainability of various biofuel practices.

The production of biofuels must not threaten environmental security or compromise humans' rights to food, water and health (Nuffield Council on Bioethics 2011). Similarly, GHG emissions from industry, transportation and deforestation are harming the environment and driving climate change; finding other ways to meet energy needs can include biofuels development (Nuffield Council on Bioethics 2011). Human well-being of current and future generations includes the provision of food, health, clean air and water, which are provided by ecosystem services (SCBD 2011). Biodiversity underpins ecosystem function and provision of ecosystem services, and provides the minimum goods essential to human life and human well-being.

Figure 7.2: Bioenergy from agriculture: factors related to biodiversity



Credit: Nieves Lopez Izquierdo (http://www.grida.no/graphicslib/tag/biofuels)

Human rights are being infringed when development actions pollute or degrade ecosystems and natural resources that humans depend on (Nuffield Council on Bioethics 2011). Severe environmental consequences that can be caused by large-scale biofuel production include destruction of biodiversity through destruction of natural habitats and pollution. Conversion of agricultural lands to biofuel production has led to deforestation through indirect land use change (iLUC), as well as depletion of water resources (Nuffield Council on Bioethics 2011).

BOX 7.1: Timeline of UN agreements on sustainable development and the environment

Listed below are some UN agreements on sustainable development that link the environment and human rights, and that are relevant to biofuels development.

- **1972 United Nations (UN) Conference on the Human Environment** was the UN's first major conference on international environmental issues, and marked a turning point in the development of international environmental politics. It was stated, "man's environment, the natural and the man-made, are essential to his well-being and to the enjoyment of basic human rights-even the right to life itself." [15]
- **The 1992 Rio Declaration on Environment and Development**[16] was produced at the 1992 United Nations Conference on Environment and Development (UNCED) (Rio Summit or Earth Summit). Twenty-seven guiding principles were adopted to guide future sustainable development around the world. The Convention on Biological Diversity was opened for signature at the Earth Summit. The **Kyoto Protocol** is an agreement of the United Nations Framework Convention on Climate Change (UNFCCC) that came out of the UNCED, which aim to control GHG gas emissions to prevent climate change. **Agenda 21**[17] was an outcome of the UNCED. It is an action plan at international, national, regional and local levels on sustainable development, including its social, economic and environmental dimensions.
- **Johannesburg Declaration on sustainable development**[18] (Johannesburg Plan of Implementation) builds on the previous declarations and was adopted at the World Summit on Sustainable Development (WSSD) (or Earth Summit 2002). The Plan of Implementation of the World Summit on Sustainable Development was also agreed at the WSSD.
- The **United Nations (UN) Millennium Development Goals**[19] (MDGs) are eight international development goals that all 193 United Nations member states and at least 23 international organizations have agreed to achieve by the year 2015. Amongst other things, they link together development and the protection of the environment.
- **Aichi Biodiversity Targets:** The Strategic Plan for Biodiversity 2011-2020 and its 20 Aichi Biodiversity Targets (SCBD 2011) is a ten-year framework for action by all countries and stakeholders to save biodiversity and enhance its benefits for people through a shared vision, a mission, strategic goals and 20 ambitious yet achievable targets. The United Nations General Assembly has also declared 2011-2020 as the United Nations Decade for Biodiversity.

15 http://www.unep.org/Documents.Multilingual/Default.asp?DocumentID=97

16 http://www.unesco.org/education/information/nfsunesco/pdf/RIO_E.PDF

17 http://www.un.org/esa/dsd/agenda21/res_agenda21_00.shtml

18 http://www.un-documents.net/jburgdec.htm

19 http://www.un.org/millenniumgoals/reports.shtml

The Five Ethical Principles of the Nuffield Council on Bioethics (2011)

A report by the Nuffield Council on Bioethics (2011) concludes there is an ethical duty to support biofuels that can satisfy five ethical principles simultaneously and to discourage biofuels that fall short on meeting one or more (Buyx and Tait 2011). These principles are as follows (quoted from Nuffield Council on Bioethics 2011):

1. Biofuels development should not be at the expense of people's essential rights (including access to sufficient food and water, health rights, work rights and land entitlements).
2. Biofuels should be environmentally sustainable.
3. Biofuels should contribute to a net reduction of total greenhouse gas emissions and not exacerbate global climate change.
4. Biofuels should develop in accordance with trade principles that are fair and recognise the rights of people to just reward (including labour rights and intellectual property rights).
5. Costs and benefits of biofuels should be distributed in an equitable way.

The Nuffield Council on Bioethics offers a sixth principle (quoted from Nuffield Council on Bioethics 2011):

6. If the first five Principles are respected and if biofuels can play a crucial role in mitigating dangerous climate change then, depending on additional key considerations, there is a duty to develop such biofuels. "These additional key considerations are: absolute cost; alternative energy sources; opportunity costs; the existing degree of uncertainty; irreversibility; degree of participation; and the overarching notion of proportionate governance."

Most biofuel production currently does not meet all these principles (Buyx and Tait (2011). The Nuffield Council on Bioethics (2011) believes that the Ethical Principles should be considered as a benchmark to evaluate technology and policy development in general and should be applied to similar technologies. They also call for regulations to ensure that both produced and imported biofuels meet human rights standards and that monitoring systems are put in place to detect abuses.

7.3 LAND RIGHTS

There is concern about large-scale biofuels plantations in developing countries infringing the rights of local farmers, farm workers, landholders and vulnerable populations (Nuffield Council on Bioethics 2011). Large biofuel producers are incentivized to scale up their production very rapidly by some governments' biofuels targets and blending mandates, causing multi-national companies and foreign investments to drive biofuels development in developing countries (Nuffield Council on Bioethics 2011; Gilbert 2011; German *et al.* 2011b). There have also been accusations of "land grabs" by some of these companies in developing countries in which indigenous tribes, customary land users and local communities have been displaced and their land cleared (Nuffield Council on Bioethics 2011). Local communities affected by these biofuels developments often lack knowledge, legal experience and capacity to negotiate equitable terms and ensure accountability. Important gaps remain concerning implications of biofuels investments, including foreign investments for local communities in developing countries, and ensuring their full and effective participation (Gilbert 2011; German *et al*. 2011b). In addition to rights issues, the alienation of local communities from land carries with it significant implications for biodiversity through the loss of associated traditional knowledge associated with biodiversity on that land, and therefore potentially undermines its sustainable use.

Other related factors in the biofuels and agriculture sectors affecting local communities include (quoted from German *et al.* 2011b):

- Ineffective environmental regulations to stop deforestation and biodiversity loss from the expansion of biofuels feedstock cultivation;
- Deficiencies in national policies and lack of enforcement of laws related to land use management;
- Persistent land and resource insecurity for the local landholders in developing countries;
- Lack of legal recognition of the rights of customary landholders;
- Lack of opportunities for smallholders in emerging markets;
- Poor internal governance of the negotiation process and benefits distribution within the affected community.

7.4 PROTECTING CUSTOMARY LAND-USERS

The rights and interests of customary land users should be increasingly considered in the context of biofuels development. Many actors are involved in inducing negative impacts on local communities and customary landholders: they may include biofuels producer and consumer governments, individual biofuels producers or companies, trade corporations, processing industry, investment banks, and financial institutions and the many strategies used to maximise profits. Market and policy failure can be blamed for the lack of opportunities for smallholders and local communities, local economic development and environmental sustainability in emerging markets, such as the biofuels sector (German *et al.* 2011b). Long-term effects of feedstock plantations on customary land users will depend on whether affected households can capture opportunities and benefits from the policies of biofuel companies or brought on by the industry. Figure 7.3 shows a generalized process of some of the major land access impacts of biofuels crops. Solutions that have been suggested to address some of these land access impacts include more widespread and enforceable corporate social responsibility, improved government oversight, and support and incentives for smallholder biofuel schemes (Gilbert 2011). Increased efforts in monitoring the practices of customary land users and determining the outcomes for them are also necessary. Strengthening and enforcing environmental protection can also support the rights of customary land users. To manage impacts of biofuels on local communities, German *et al.* (2011b) suggest a combination of regulatory and market-based instruments functioning at different scales. Some examples are summarised in the bulleted list below.

Some priorities for governments involved in large-scale feedstock production:

- Legislate the protection of customary land rights and increasing the recognition of those rights.
  - Simplify registration procedures for customary landholders and recognize the rights for those without formal registration, to allow the poorer households to also secure their rights. However, the laws are not always effectively implemented and enforced, as seen in large land acquisitions for biofuels in sub-Saharan Africa and Southeast Asia (Colchester 2011, German *et al.* 2011b).
  - Extend protection beyond customary leaders to all affected households and mandate compensation of land, land investments and other natural resources (Cotula 2011; Colchester 2011; German *et al.* 2011b).
- Legislate free prior and informed consent as a procedure when acquiring land from customary land users.
- Enhance ability for local communities to defend their rights: e.g., legal literacy, the importance of specificity in the written agreement and understanding the long-term consequences of the land transfer.
- Restrict the total land area that an agribusiness may hold to enhance smallholder participation and bargaining power.
- Constrain agreements in time to enhance resilience and adaptive capacity in the face of changing markets and socio-economics.
- Governments should research the types of development activities, services or inputs needed by smallholders for economically and environmentally sustainable production.

BOX 7.2: Effects of biofuel production on customary livelihoods in the global south (review of case studies by German *et al*. 2011)

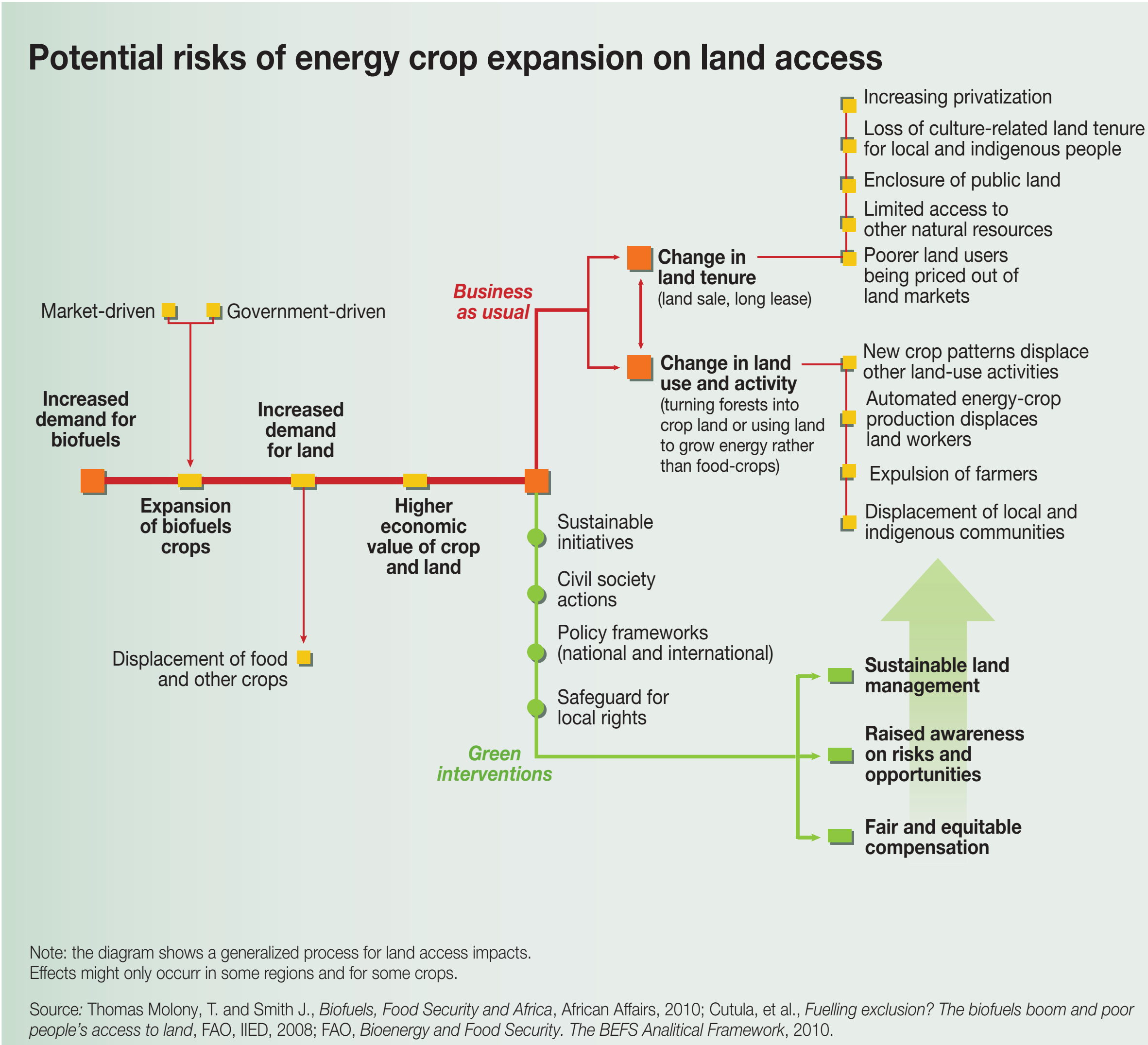
Displacement of customary livelihoods resulting from large scale land transfer to investors was considered the most negative impact of biofuel cultivation in case studies of 12 landscapes in six countries in the global south, reviewed by German *et al*. (2011b). These negative impacts are due to economic losses for the local people in agricultural and forest income and the failure to channel the potential benefits of biofuels to affected households. Negative impacts from the displacement of customary landholders were only observed in industrial-scale plantations and were not observed in smallholder plantations, where the land-use decisions are voluntary. In most of the sites where there were industrial-scale plantations, customary land users were neither consulted nor informed prior to agreements being closed, and in some cases nor when the land clearing began. In general, poor governance in payments, variability of payments, failed delivery and inferior quality of goods and services rendered caused conflict and dissatisfaction. Some customary leaders requested additional compensation or their land back after the lease ended.

The key problem appears to lie in the process by which investors acquire land under customary use and ownership. Processes of land acquisition varied greatly in the case studies: Brazil and Mexico use voluntary transactions between land sellers and buyers, while other counties have land acquisition processes where the customary land rights are informal and not sufficiently recognized by the government and investors. Customary land users and authorities can also be manipulated by outside actors through an unfair advantage in terms of the knowledge, power and awareness of the law, and easily persuaded by promises of development. For example, in German *et al.* 2011b, some agreements were made in advance of consultations with locals or never committed to paper. Other agreements compensated highly variable amounts to villages in the same concession area. Elite capture was also seen as a significant risk where alienation rights were entrusted in the customary leadership and deals were undisclosed or negotiated for reasons personal interest.

Declines in food security have been observed throughout the global south due to biofuels developments (German *et al.* 2011). In sites in Southeast Asia, decreased forest cover due to biofuels plantations resulted in local people reporting greater difficulty in accessing forest products and practicing shifting agriculture. In Indonesia, it was found that livelihoods with more traditional land uses had declined more significantly as a result of biofuels plantations. Benefits for the local smallholders increased where they had prior experience with oil palm. In the case study in Ghana, the 780 ha that were cleared for biofuels plantations affected 69 households, where the average household lost ¾ of its land (Schoneveld *et al*. 2011). Few were able to purchase replacement land, and if so, it was only a fraction of initial landholdings. In Ghana, 73% of respondents (n=63) found overall declines in their standard of living; 98% reported declines in forest related activities and 73% reported declines in agricultural activities. This case study demonstrated marked declines in food security, even in landscapes with low population densities (Schoneveld *et al.* 2011).

Smallholder biofuels feedstock cultivation is likely to have a greater positive impact on local communities than industrial-scale production, especially when the smallholders are from countries where there is a longer history of feedstock cultivation (German *et al.* 2011b). However, industrial-scale plantations are more likely to be able to compete in the international market due to more capital to invest in specialized crops and more knowledge of market opportunities (German *et al.* 2011b). In Malaysia and Indonesia, it was found that small-scale growers had increased income, more flexible working hours and improved infrastructure (German *et al.* 2011b). Brazil provides incentives to encourage biofuel producers to obtain their feedstocks from smallholders (defined as farms less than 100 ha) under the Social Fuel Seal program. However, farms much less than 100 ha, are also often excluded (Lima *et al.* 2011; German *et al.* 2011b).

Figure 7.3: Potential risks of energy crop expansion on land access



Credit: Riccardo Pravettoni, UNEP/GRID Arendal (http://www.grida.no/graphicslib/tag/biofuels)

7.5 INVESTORS

Foreign and domestic investors, governments and entrepreneurs share a large responsibility in ensuring that biofuels meet social and environmental standards (Van Gelder and German 2011). Most private and public investors have not sufficiently addressed sustainability concerns because they lack sustainability policies or they are of insufficient quality (Van Gelder and German 2011). Large investments have been needed to finance rapid expansion, and there are a multitude of groups of investors involved in the biofuels sector, both domestic and foreign (listed in the bullets below) (Van Gelder and German 2011). Foreign banks and foreign institutional investors play a more important role in the Africa and Asia, and are of moderate importance in Latin America. Van Gelder and German (2011) estimated that a total of US$25.2-35.7 billion was invested in 2000-2009 for growing feedstock, of which US$5-6 billion dollars was for producing biofuels in the 20 country-feedstock pairs reviewed. US$3.8-4.2 billion was invested in sugar cane-based ethanol production in Brazil. Other countries with significant investments include Columbia, Indonesia and Malaysia, and soy-based biodiesel in Brazil.

Types of investors for biofuels (quoted from Van Gelder and German 2011):

- Domestic and foreign entrepreneurs owning feedstock and/or biofuel companies;
- Domestic governments providing subsidies and investment incentives as well as loans through national development banks, making infrastructure investments and owning companies investing in the biofuel sector;
- Foreign governments providing development aid, (soft) loans or foreign investment incentives, or owning companies which invest abroad;
- Domestic and foreign banks providing loans and assisting companies in issuing stocks;
- Domestic and foreign institutional investors, including pension funds, insurance companies and asset managers, buying shares and bonds of companies in the sector;
- Multilateral financial institutions providing loans and other investments.

Private investment institutions that finance biofuels should apply "responsible investment instruments", which are based on policies that set out social and environmental principles, criteria and indicators (Van Gelder and German 2011). Responsible investment instruments are becoming more common in financial institutions and can be applied on a voluntary basis. Although, if they are to be effective, they need to be of good quality and must be adopted by a significant number of financial institutions. Many financial institutions have signed on to the Principles for Responsible Investment[20] (PRI), which is a UN-backed network of international investors incorporating environmental, social, and corporate governance (ESG) issues, investment analysis and decision-making processes (UNPRI 2012). Social and environmental conditions tied to forms of public finance and government regulations can also help private financial institutions in applying responsible investment instruments (Van Gelder and German 2011). They must also be of sufficient quality and adopted by many governments to be effective. They should be derived from internationally recognized standards, and mechanisms for monitoring and compliance must be in place.

Although, there are few initiatives applying social and environmental conditions to finance, **there are some examples of government regulations helping private financial institutions apply these conditions** such as the Socially Responsible Investing (SRI) Pensions Disclosure Regulation in the UK. In China, the Green Credit Policy was put in place in 2007, creating a "credit blacklist" for banks to stop lending to companies that do not demonstrate environmental responsibility. Corporate Social Responsibility (CSR) reporting requirements can help financial institutions be more transparent and make more informed decisions regarding social and environmental impacts. The Global Reporting Initiative (GRI)[21] is a non-profit initiative that endeavours to make sustainability reporting, on economic, environmental, social and governance performance by all organizations as regularly as financial reporting.

7.6 CONTRACT FARMING OR OUT-GROWER SCHEMES

Contract farming or out-grower schemes, where farmers have an agreement with a buyer or processing plant, can enhance rural development by providing smallholders with:

- Smallholder access to local markets
- Access to improved seeds
- Access to inputs
- Mechanization and transport services
- Extension advice; and
- Credit

20 http://www.unpri.org/principles/

21 http://database.globalreporting.org/

Contract farming can be beneficial for smallholders to ensure access to fertilizer, seeds and other inputs. Fertilizers are often more expensive in developing countries due to decreasing agricultural subsidies and price inflation, resulting in declines of the rate of application. However, some farmers may adopt a new crop through contract farming to gain incentives and inputs, but may end up failing to be more profitable, or it may be several years, depending on the crop, before profits are made. Furthermore, it is recommended in German *et al.* (2011b) that contract be negotiated on an annual basis to avoid risks to farmers.

7.7 STAKEHOLDER ENGAGEMENT

The balance between development, environmental and social concerns can better be managed in biofuels development projects if there is a continuous dialogue between the different stakeholders (UNEP 2010b; UN-Energy 2010). Decision-making in developing countries is often driven by investors, who may overlook concerns of the local community. Nevertheless, stakeholders can affect business and risks can be high for investors if stakeholders are not consulted. Strengthening stakeholder engagement on the ground can ensure concerns are addressed before they become problems and help reduce unrest in the community. Capacity-building so that stakeholders fully understand the issue and the process may be necessary. Certain modes of communication may not be appropriate for all groups, e.g., oral communication with simple maps and diagrams can be more effective with local communities (UNEP 2010b; UN-Energy 2010).

Stakeholder participation, engagement in decision-making and monitoring progress are crucial in ensuring that the local communities benefit from biofuels development, and for negative impacts to be prevented (UNEP 2010b; UN-Energy 2010)**.** This ensures transparency and social accountability in decision-making and that all the different concerns are heard and taken into account, particularly for people most affected by biofuels development. When actively involved in monitoring, stakeholders can also notify authorities if unanticipated problems occur that need managing. Local communities that are highly impacted by a potential project or policy often have the least level of influence in the planning process and they should be given particular attention (UNEP 2010b; UN-Energy 2010).

BOX 7.3: National level stakeholders (simplified from UN-Energy 2010)

National Level stakeholders may include:

- Government ministries/authorities in relevant sectors (e.g., energy, agriculture, environment, water, finance);
- Representatives of regional/local government;
- Agricultural extension providers/ organizations;
- Energy-related parasatals (state-owned organizations);
- Community-based or international NGOs for the environment, development, labour, trade, farmers;
- Private sector (e.g., producers, distributors and users of biomass, research agencies);
- Financing institutions;
- Bilateral and multilateral organizations in development cooperation.

When designing policies, it is recommended that a bioenergy strategy be guided through a multi-stakeholder, multi-sectorial approach to balance concerns of various stakeholders, which could include academics, NGOs, community leaders, civil society and interest groups. UNEP (2010b) and UN-Energy (2010) recommend that a Task Team or Task Force (Steering Committee) be put in place as the executive organ facilitating decision-making. This can be coordinated by a government representative from a relevant sector. The Task Force should be extended into implementation, monitoring and evaluation. The second step is the creation of a Stakeholder Forum where anyone interested can participate, representing a variety of interests beyond the Task team, which may have chambers or sub-committees. The Task Force must report back to the stakeholder forum at each step of the process and invite feedback. Interests may vary depending on country or region but they should represent a range of interests amongst social, environmental and economic concerns. It is often necessary to seek out these stakeholders and interests groups, and facilitate their participation. An independent facilitator can be necessary to avoid bias in negotiations. It is key to involve stakeholders early on and keep the process alive throughout. At the project level, only the Stakeholder Forum may be necessary. However, it is not sufficient to solely involve the community leader; women, youth, labour, farmers (etc…) should also be involved.

Principles, criteria and indicators are available that support effective stakeholder engagement. These can be global standards, multi-stakeholder certification schemes or international treaties. For feedstock production and processing, there are standards developed by multi-stakeholder initiatives, such as the Forest Stewardship Council, the Roundtable on Sustainable Palm Oil and the Roundtable on Sustainable Biofuels (see Box 2.2) (Van Gelder and German 2011).

8. THE PRIMARY NEED: BROADER LAND AND RESOURCE USE PLANNING

The key issue regarding sustainable biofuel production and use, with regards to biodiversity, concerns the broader issue of sustainable consumption and production under multiple pressures. Most of the major unresolved issues with biofuels centre on the need for sustainable land, and other resource use and planning. The extent to which sustainable biofuels can be achieved depends upon the progress in achieving sustainability with other land use activities, particularly by agriculture. For this reason, many forums, including the FAO, consider biofuels under the broader framework of sustainable agricultural (and as appropriate, forestry) production. An information gap is whether the current attention to sustainability for biofuels is matched in agriculture in general and the extent to which the tools and approaches for biofuels are being applied beyond biofuels, where arguably they are required even more urgently

Competition of biofuels for resources (e.g. land, water, inputs) with food and inter-relationships with food security is widely discussed; however, biofuels are not alone in having an ethical dimension. Much of the world's agricultural production has little to do with food security, including food that supports lifestyles (not essential food), unhealthy diets and over consumption and a considerable level of resources are used to produce fibres (much of which caters to the "whims of fashion") and cosmetics. Furthermore, Gustavsson *et al.* (2011) suggest that about one-third of food is wasted; others have suggested that as much as half of all food grown is lost (Lundqvist *et al.* 2008); and some perishable commodities have post-harvest losses of up to 100% (Parfitt *et al.* 2010).

Land is becoming an increasingly scarce resource under competing uses and increasing pressure from a growing world population, climate change and land degradation (Lambin and Meyfroidt 2011). The issue still remains as to whether there is enough land on Earth to accommodate all future land uses, including the cultivation of biofuel feedstocks (Lambin and Meyfroidt 2011). Currently, sufficient information does not exist on global land use to consider competing demands against the supply of land, and to consider choosing between competing options (Nuffield Council on Bioethics 2011). Breakthroughs in genetically modified crops, second and third generation biofuels, increasingly vegetarian diets in rich countries and strict land use planning are necessary to prevent accelerated conversion of natural forests, cropland expansion into unsuitable lands, which would require intensive use of fertilisers and water (Lambin and Meyfroidt 2011). Land-use zoning has been brought forward as a potential solution to looming land scarcity. Land-use zoning schemes assign land to specific uses to safeguard natural ecosystems. Still, land-use zoning may indirectly affect land use in other countries through compensatory changes in trade flows. Sustainable intensification is another proposed solution to land scarcity for agricultural commodities. It is generally assumed that if agriculture is intensified, less land is needed, and forests can be preserved. But, if intensification increases the profitability of a product, especially in terms of cash crops in global markets, it is possible that expansion of cultivated area could occur (Lambin and Meyfroidt 2011).

Land use policy and planning involves balancing multiple interests and objectives, including working in a regional and international framework (Nuffield Council for Bioethics 2011). A comprehensive and equitable approach to land use policy and planning that includes the necessary incentives would require much work and negotiations to be implemented. Since this will not be possible in the short term, developing integrated land use planning at the national level is the priority. This should include agricultural, environmental and social considerations and the consideration of indirect effects (or leakage) of unsustainable practices into other areas (Nuffield Council for Bioethics 2011). An example is the Brazilian government's agro-ecological zoning policy *ZAE Cana* of 2009 that limits sugar cane production into areas where there would be less of an environmental impact. This land zoning policy includes mandatory environmental, social, economic and soil restrictions, which have had some positive effects to reduce deforestation and water pollution, and to protect valuable forest land (from Nuffield Council for Bioethics 2011). Another example which has had some positive outcomes is the Food and Agriculture Organization

(FAO) Bioenergy and Food Security (BEFS) Project (available at: http://www.fao.org/bioenergy/foodsecurity/befs/en/), which aims to build national capacity and collect data to form a basis for agro-ecological zoning.

Increased synergy and coordination between biofuels, ecosystem-based approaches to climate change mitigation and integrated land-use planning can better address the needs of biodiversity, ecosystem services and people. Avoiding or reducing deforestation, for example through REDD+[22], as well as improving forest management may help maintain ecosystem services and carbon stocks, thereby mitigating climate change, conserving biodiversity and producing biomass for bioenergy. Similarly, when appropriately designed and managed, reforestation activities on degraded lands can also relieve pressure on natural forests by supplying alternative sources of sustainable wood products, including bioenergy, while contributing to climate change mitigation (SCBD 2009). Furthermore, the use of modern bioenergy in developing countries can be a much more sustainable alternative to harvesting fuel wood for local communities, and in this case, REDD+ could also complement bioenergy activities by reducing deforestation (UNEP 2012b). Afforestation on degraded lands, as seen in Tilman *et al.*'s (2006) study (see Box 1.1), where high diversity native prairie grasses were grown as biofuel feedstock, led to net sequestration of atmospheric CO_2 and provided a carbon negative biofuel. Similarly, improving agricultural management can make a significant contribution to climate change mitigation and biodiversity conservation: conservation tillage, agroforestry systems, reducing inputs and water needs, and restoration of degraded croplands all increase carbon sequestration potential and conservation of biological diversity (SCBD 2009).

22 Reducing emissions from deforestation and forest degradation and the role of conservation, sustainable management of forests and enhancement of carbon stocks in developing countries.

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