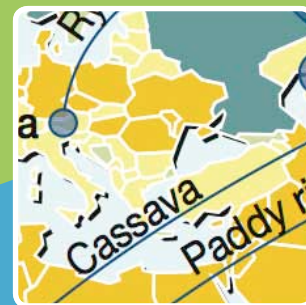
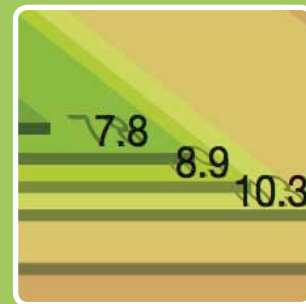
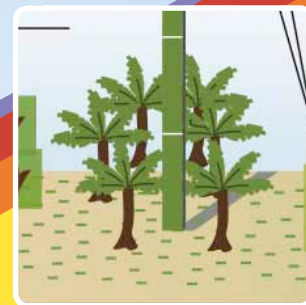


Biofuels Vital Graphics

Powering a Green Economy



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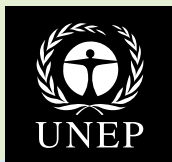
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Biofuels Vital Graphics

Powering a Green Economy



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Preface.

Biofuels Vital Graphics:

Powering a Green Economy

Liquid, gaseous or solid biofuels hold great promise to deliver an increasing share of the energy required to power a new global green economy. Many in government and the energy industry believe this modern bioenergy can play a significant role in reducing pollution and greenhouse gases, and promoting development through new business opportunities and jobs. Modern bioenergy can be a mechanism for economic development enabling local communities to secure the energy they need, with farmers earning additional income and achieving greater price stability for their production.

But it is not that simple. Biofuels remain a complex and often contentious issue. Over the past few years the risks of competition with food production and potential negative impacts on the atmosphere, biodiversity, soil and water have been highlighted. The way biofuels are made and used is critical: they may either help mitigate or contribute to climate change, reduce or exacerbate impacts on ecosystems and resources.

Issues related to biofuels are complex and interconnected: they require solid planning and balancing of objectives and trade-offs. Safeguards are needed and special emphasis should be given to options that help mitigate risks and create positive effects and co-benefits.

Biofuels Vital Graphics is designed to visualise the opportunities, the need for safeguards, and the options that help ensure sustainability of biofuels to make them a cornerstone for a Green Economy. It is meant as a communications tool, rather than providing new analysis. It builds on a 2009 report by the International Panel for Sustainable Resource Management of the United Nations Environment Programme, Towards Sustainable Production and Use of Resources: Assessing Biofuels, and refers to research produced since.

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Introduction.

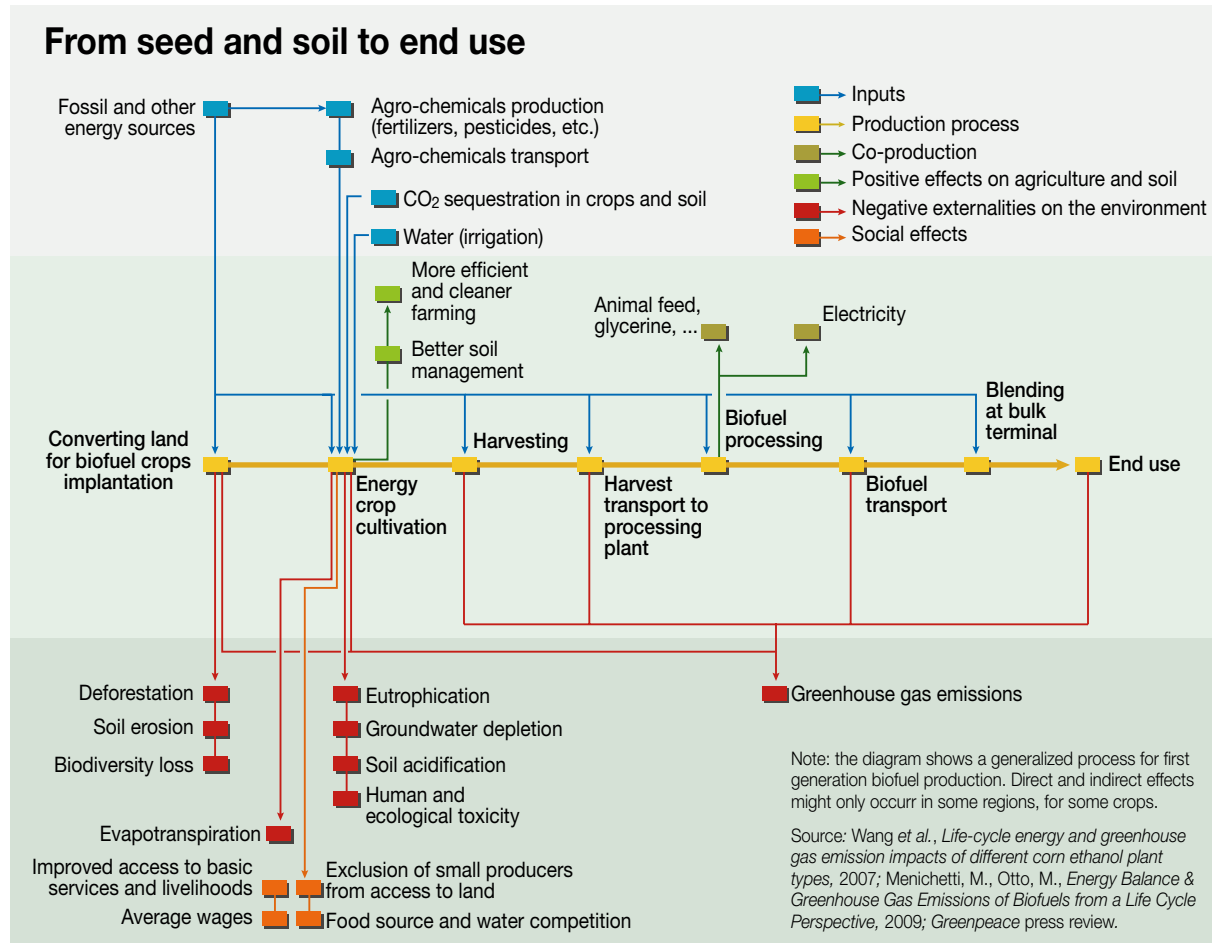


Figure 1.1 From seed and soil to end use

Biofuels Vital Graphics aims to highlight opportunities offered by a developing biofuels sector, and the need for safeguards. Long-term and comprehensive planning can address different environmental and social concerns both as a means to achieve sustainability, and as a pre-condition for the successful development of the biofuels sector.

the opportunities offered by a developing biofuels sector...

As with every other energy source, biofuels entail some risks and should be assessed over their entire lifecycle. For example the graphic, From seed and soil to end use, tracks the lifecycle of liquid biofuels for use in the transport sector – most of the available analysis has focused on this part of the sector, but it is increasingly recognised that biofuels are more than just transport fuels – from the moment land is converted for the purpose of growing biofuel crops, to the end use of the biofuel product in a vehicle. The graphic shows how various inputs to the production process create outputs with environmental and social impacts. Environmental and social issues related to the use of crops grown as biofuel feedstocks are similar to such issues raised in the agricultural sector as a whole, and are applicable to crops used for biomaterials, bioplastics and other products, too.

Life - Cycle Assessment (LCA) is a tool, which allows comparison of various biofuel pathways. It shows that not all biofuels are created equal, with impacts depending on many variables. It is critical that LCAs cover a broad range of impact categories to allow for a holistic assessment, rather than comparison of a single element, such as greenhouse gas emissions (GHG).

need for safeguards...

One biofuel end-product, for example, might have a positive GHG balance but a serious impact on water, or it might have environmental benefits but cause social impacts. Yet again it might have very detrimental, possibly irreversible impacts.

Box 1.1 Life-Cycle Assessment

Life-Cycle Assessment (LCA) is a tool devised for evaluating the environmental impact of a product, process or service through its life cycle, also referred to as its 'environmental footprint'. All inputs and outputs of material, energy, water and waste over the entire product life cycle and their relative impacts are accounted for, including the extraction of raw materials, processing, manufacturing, transport, use and disposal. The main objective of an LCA is to compare the impacts of several alternative processes in order to choose the least damaging one.

Source: UNEP (2011) Towards a Green Economy. Pathways to Sustainable Development and Poverty Eradication. A Synthesis for Policy Makers

In three main chapters Biofuels Vital Graphics first explores the potential of biofuels to become a component of the green economy, following on with a discussion on safeguards, with special emphasis on mitigating risks related to land and water-use as key natural resources for biofuel production. The publication concludes with a set of options for facilitating the development of a sustainable bioenergy sector.

Definitions

Figure 1.2 illustrates the various feedstocks, which can be converted to biofuels for transport. However, this represents only part of the larger bioenergy family, which covers liquid, solid and gaseous biofuels for different uses, including electricity production, and the traditional biomass for energy use.

not all biofuels are created equal...

For the purposes of this publication, some definitions are outlined below. Biofuels Vital Graphics recognises the commonly used distinctions between first, second and third-generation biofuels based on the type of feedstock, conversion technology and end-product. But the authors advocate distinctions based on sustainability, better suited to policy-making and planning.

Box 1.2 Key terms

Biomass is plant and animal matter, including micro-organisms (such as algae).

Biofuels are combustible materials directly or indirectly derived from biomass. Liquid biofuels, such as bioethanol and biodiesel, are generally used for transport; biogases are used for stationary applications such as electricity generation; and solid biofuels for electricity generation and heating.

Bioelectricity refers to electricity generated from a biofuel or directly from a biomass feedstock.

Bioenergy is defined as energy produced from organic matter or biomass.

Traditional bioenergy refers to unprocessed biomass which does not go through a conversion process, but is directly combusted; including agricultural residues, wood and charcoal.

Modern bioenergy refers to biomass that may be burned directly, further processed into densified and dried solid fuels, or converted into liquids or gaseous fuels. It includes biofuels for transport, and processed biomass for heat and electricity production.

Feedstocks are crops and other materials used to make modern forms of bioenergy.

First-generation biofuels refer to biofuels made from sugar, starch, vegetable oil, or animal fats using conventional technology. The most common first-generation biofuels are bioethanol and biomethanol, followed by biodiesel, vegetable oil and biogas.

Advanced biofuels comprised so-called second and third-generation biofuels, as well as hybrids with first-generation biofuels. These are produced primarily from cellulose, hemicellulose or lignin, found in residues from forestry, corn stover (the dried stalks and leaves of maize after harvest), bagasse, wheat straw, and algae. Lignocellulosic technology converts the cellulose stored in the cell walls of the plant into products that can be processed in the same way as first-generation biofuels.

Source: UNEP (2009) Assessing Biofuels, UN-Energy (2007) Sustainable Bioenergy: A Framework for Decision Makers, <http://esa.un.org/un-energy/pdf/susdev.Biofuels>.FAO.pdf

The enlarged biofuels family

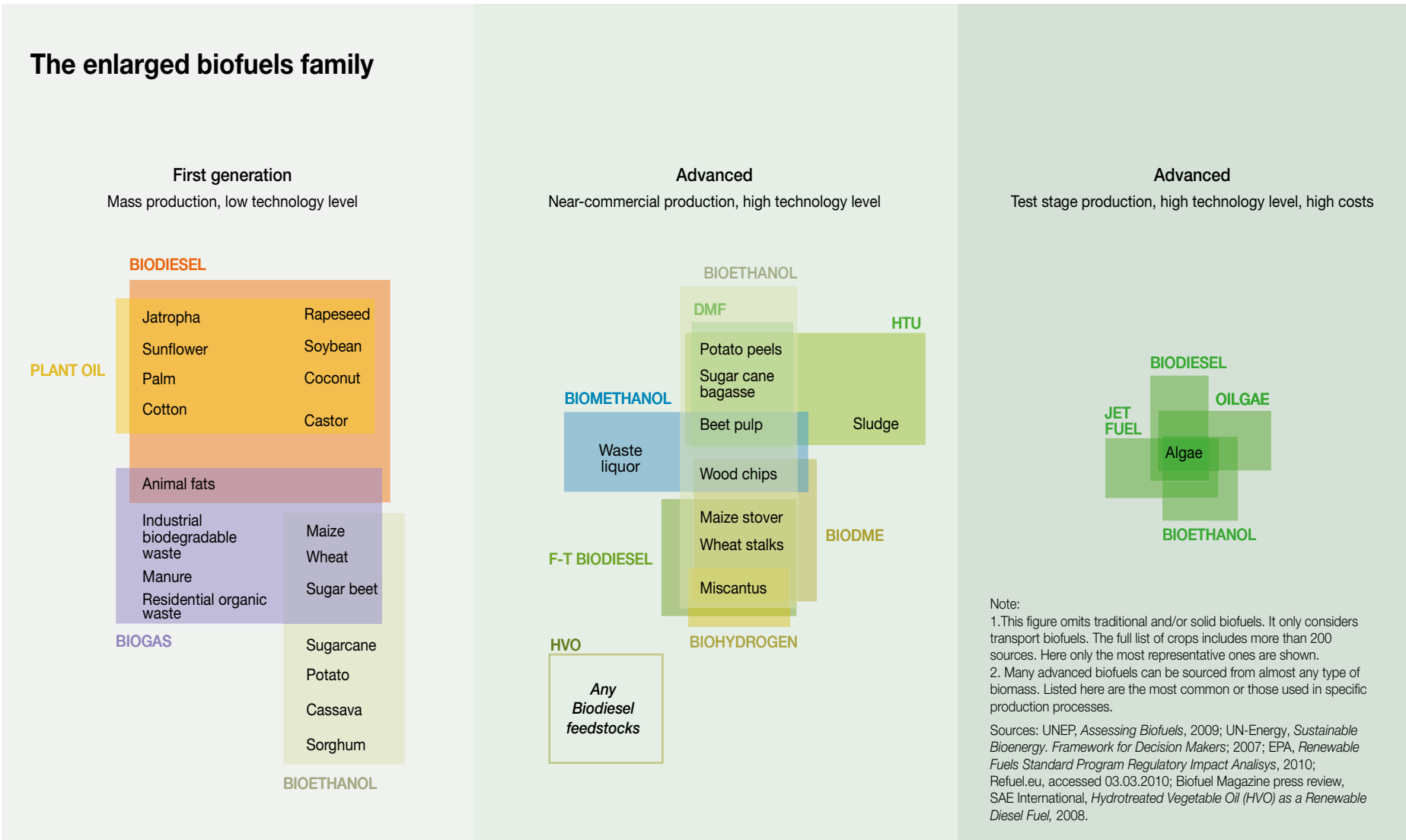


Figure 1.2 The enlarged biofuels family

Building a Green Economy.

A Green Economy follows an economic model in which business and infrastructure are reconfigured to deliver better returns on natural, human and economic capital¹. Actions that can contribute to this include introducing measures for reducing greenhouse gas emissions, more efficient and thoughtful use of natural resources, and reduced social disparities. Ideally, a green economy is one in which economic growth is decoupled from environmental impacts and or resource use, including the consumption of land, material and energy resources.

To date, energy use and economic growth have been closely linked. As Figure 2.1 shows, there is a linear relationship between energy consumption and wealth as measured in the Gross Domestic Product (GDP) of nations.

In building a green economy, the energy sector has a different part to play by replacing fossil fuel with low-carbon options. It may also contribute to implementing a green-economy strategy incorporating greater energy-efficiency and renewable energy sources. These are key approaches in supporting growth in GDP, whilst avoiding a continuation of the linear relation to energy demand. Biofuels are among the potential low-carbon options. And they provide, particularly in many developing countries, scope for harnessing biomass resources and the agricultural sector to develop indigenous industries.

1. The UNEP Green Economy Report released in February 2011, outlines the public policy options, urgent actions and investments needed to a global 'Green Economy' – one that is low-carbon, resource-efficient and socially inclusive.

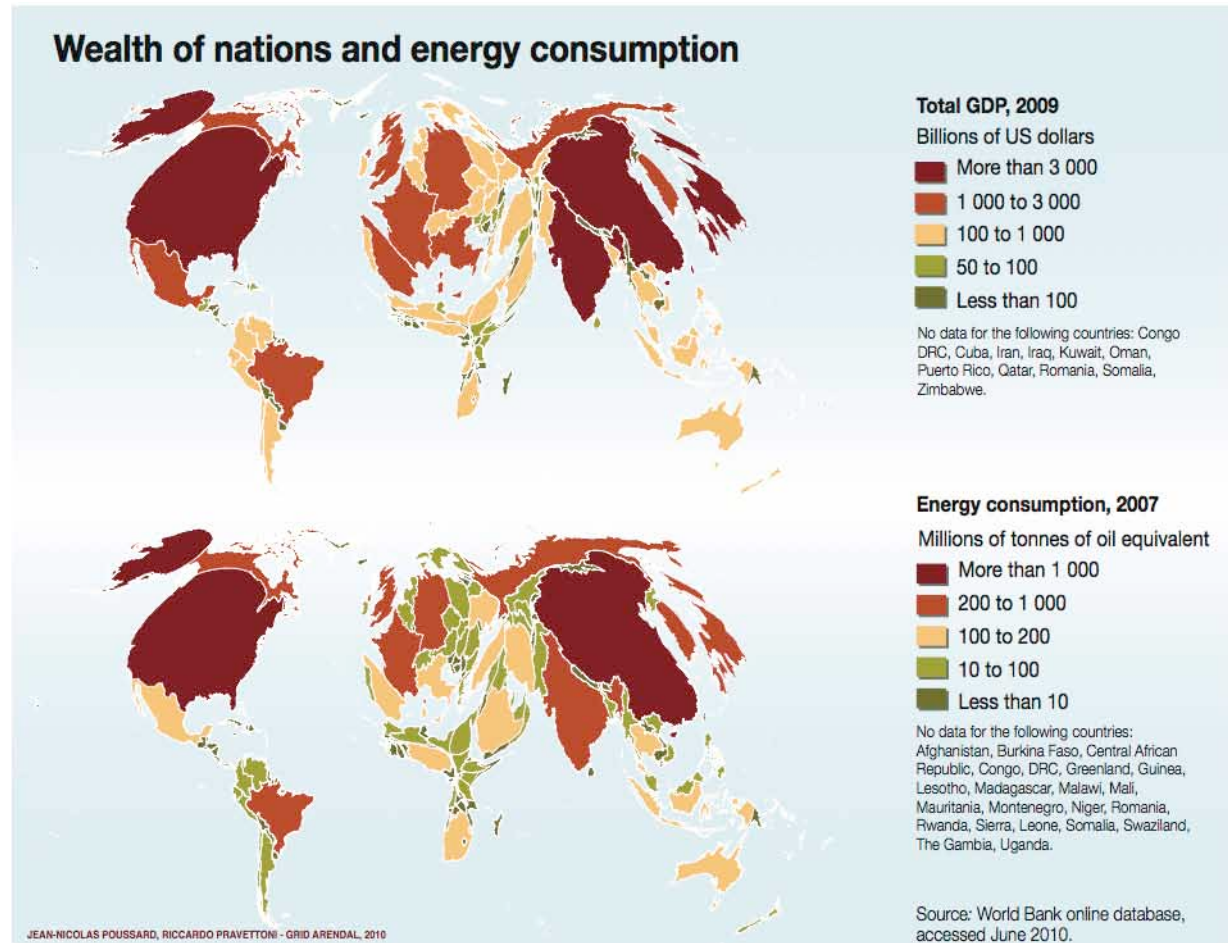


Figure 2.1 Wealth of nations and energy consumption

If properly planned and managed, biofuels can contribute to a number of policy objectives which support the development of the green economy, including:

- Diversity and security of energy supplies.
- Many nations have the ability to produce their own biofuels from agriculture, forestry and urban wastes. Produced locally, bioenergy can reduce the need for imported fossil fuels – often a serious drain on a developing country’s finances. By diversifying energy sources, biofuels can also increase a country or region’s **energy security**.
- **Rural development.** With 75 percent of the world’s poor depending on agriculture for their livelihoods, producing biofuels locally can harness the growth of the agricultural sector for broader rural development.
- Because agriculture is labour-intensive, **job opportunities** can be found throughout the biofuel value chain, particularly where conversion from feedstock to biofuel occurs close to where the feedstock is produced. The additional income from new jobs is likely to have a multiplier effect when spent locally, which can further encourage development. Higher quality energy from biofuels can reduce the time needed to collect water and firewood, which means that many women and children have more time for study and other productive tasks.
- Job growth and creation is a primer for the green economy where each renewable energy technology needs different labour and skills. Jobs

in the bioenergy sector are projected to make the greatest contribution to employment compared to all the other renewable energy sectors. However, the factors that increase or decrease this potential include the level of mechanisation, agricultural business models, and available human capacity.

- **Energy Access** Currently more than 1.5 billion people have no access to electricity and up to 1 billion more have access only to unreliable power supply. And according to estimates by the IEA, 2.5 to 3 billion people rely on biomass and transitional fuels for cooking and heating. Biofuels can help provide access to energy for energy-deprived and off-grid communities, thereby contributing to the goal of universal access to modern energy services by 2030 and spurring greater economic development.
- **Health benefits** When biofuels replace the traditional inefficient combustion of biomass, indoor pollution is reduced along with subsequent health impacts.
- **Reduced greenhouse gas emissions** Biofuels that replace fossil fuels or traditional use of biomass for energy can reduce GHG emissions. However, the potential to live up to this promise depends on the GHG balance during production and conversion of biofuels. For example, in many developed countries liquid biofuels for transport have been identified as one of several measures to achieve emission-reduction targets under climate change commitments.

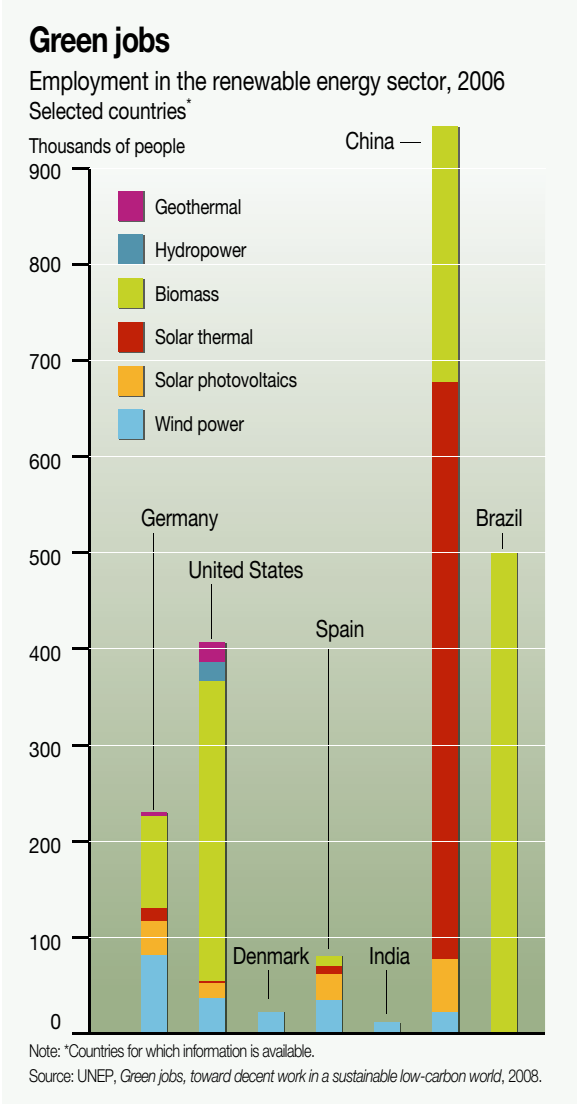


Figure 2.2 Green jobs

Bioenergy in all its forms has been, and will continue to be, a part of the energy mix. Biofuels, as one form of bioenergy, can be an important component in the effort to replace fossil fuels with renewable energy, as well as being a factor in achieving the 2°C climate goals. The actual energy mix and potential for sustainable biofuels development, however, depends on individual countries' conditions and needs.

Most of the potential for growth in biomass production is in developing countries, particularly in tropical regions where the conditions are most favourable for producing feedstocks. In these regions developing countries have a significant opportunity to create both a domestic industry and engage in international trade.

Studies indicate that global bioenergy use is approximately 10 percent of the global energy mix, with a growth rate of 1.3 percent per year. Future projections for the supply of bioenergy are shown in the 2.3 figure. The analysis is based on four scenarios for environmental targets, based on technical potentials that differ depending on agricultural efficiency, production systems, technology and water supplies.

The scenarios span a wide range of global bioenergy potentials, and experts argue that the high-end projections play down technical constraints such as available land or realistic yields. It seems the potential of bioenergy crops is at the lower end of the range and is associated with integrated optimisation. Researchers say that future capacities of bioenergy, and biofuels in particular, lie in residues from agriculture and forestry.

World bioenergy technical potential in 2050

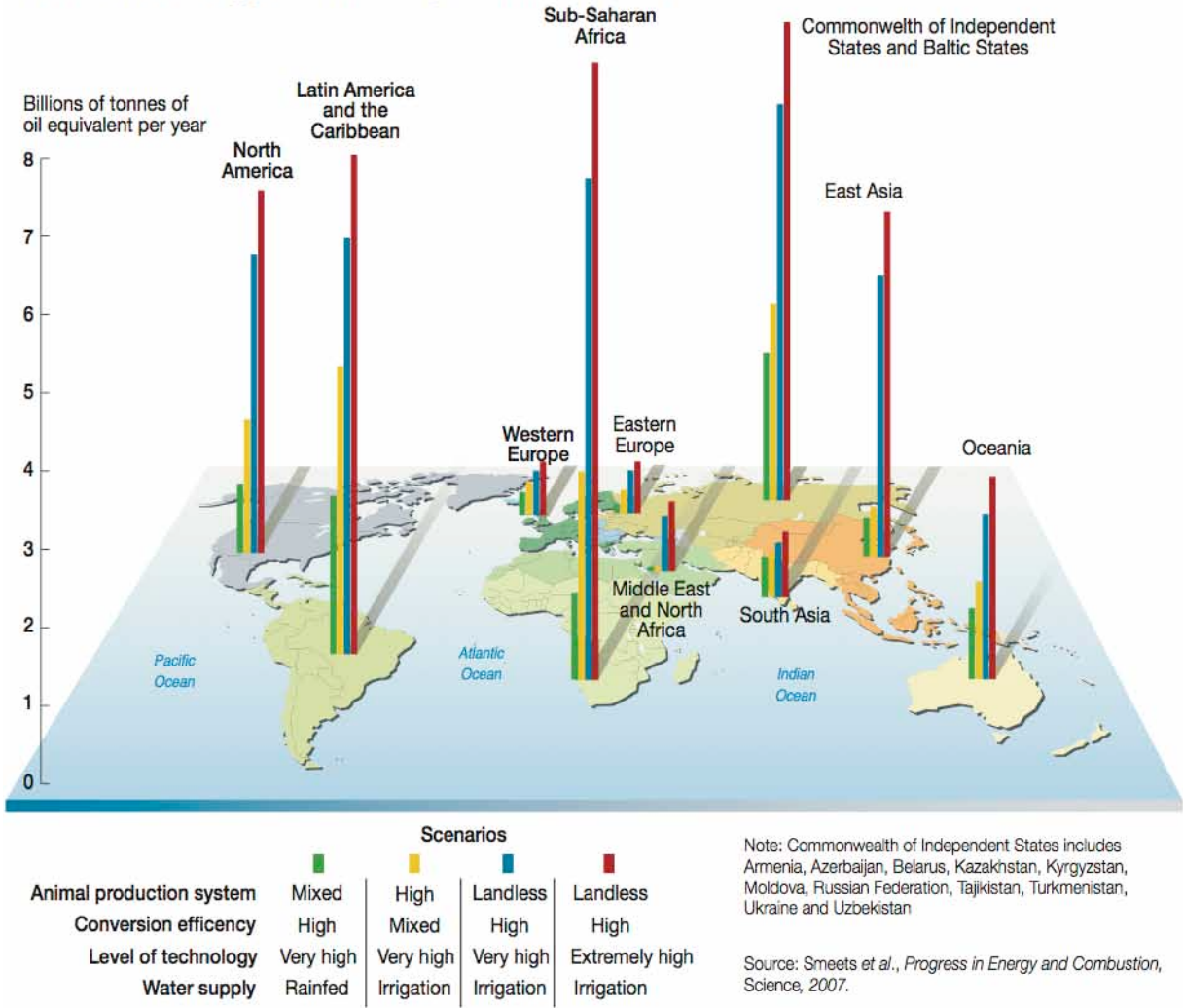


Figure 2.3 World bioenergy technical potential in 2050

Bioenergy in all its forms has been, and will continue to be, a part of the energy mix...

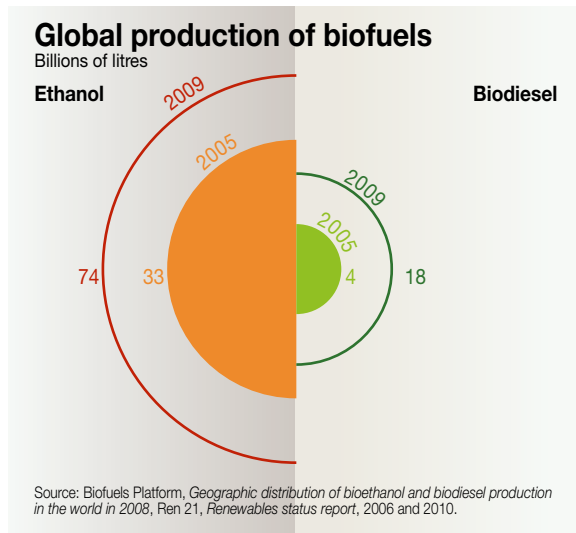


Figure 2.4 Global production of biofuels

Liquid biofuels provided 2.7 percent of all global road transport fuels in 2009. The snapshot of biofuel production in Figure 2.5 shows global ethanol production currently concentrated in two countries. The snapshot for biodiesel production in Figure 2.6. shows a similar but slightly more diversified picture.

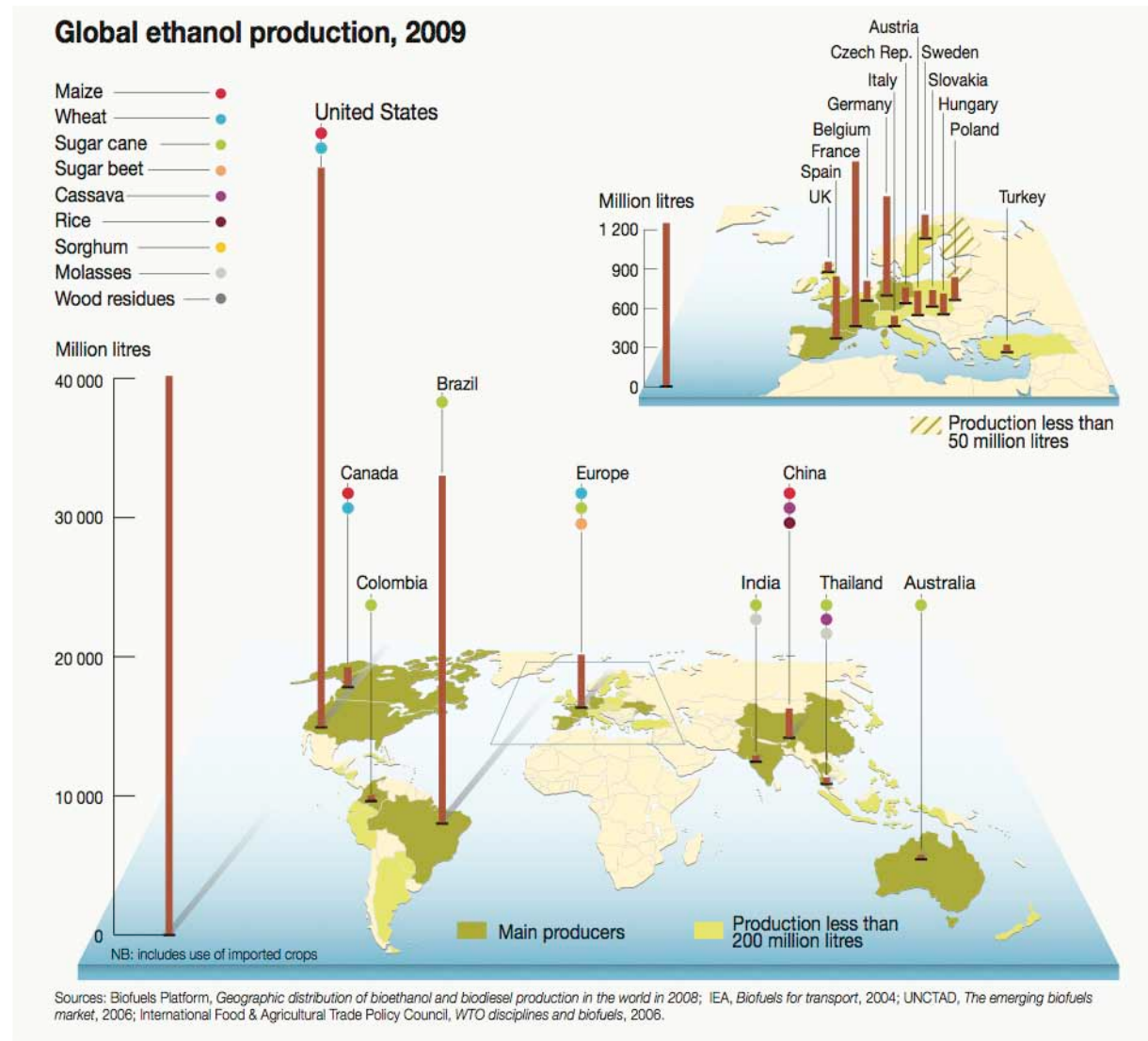
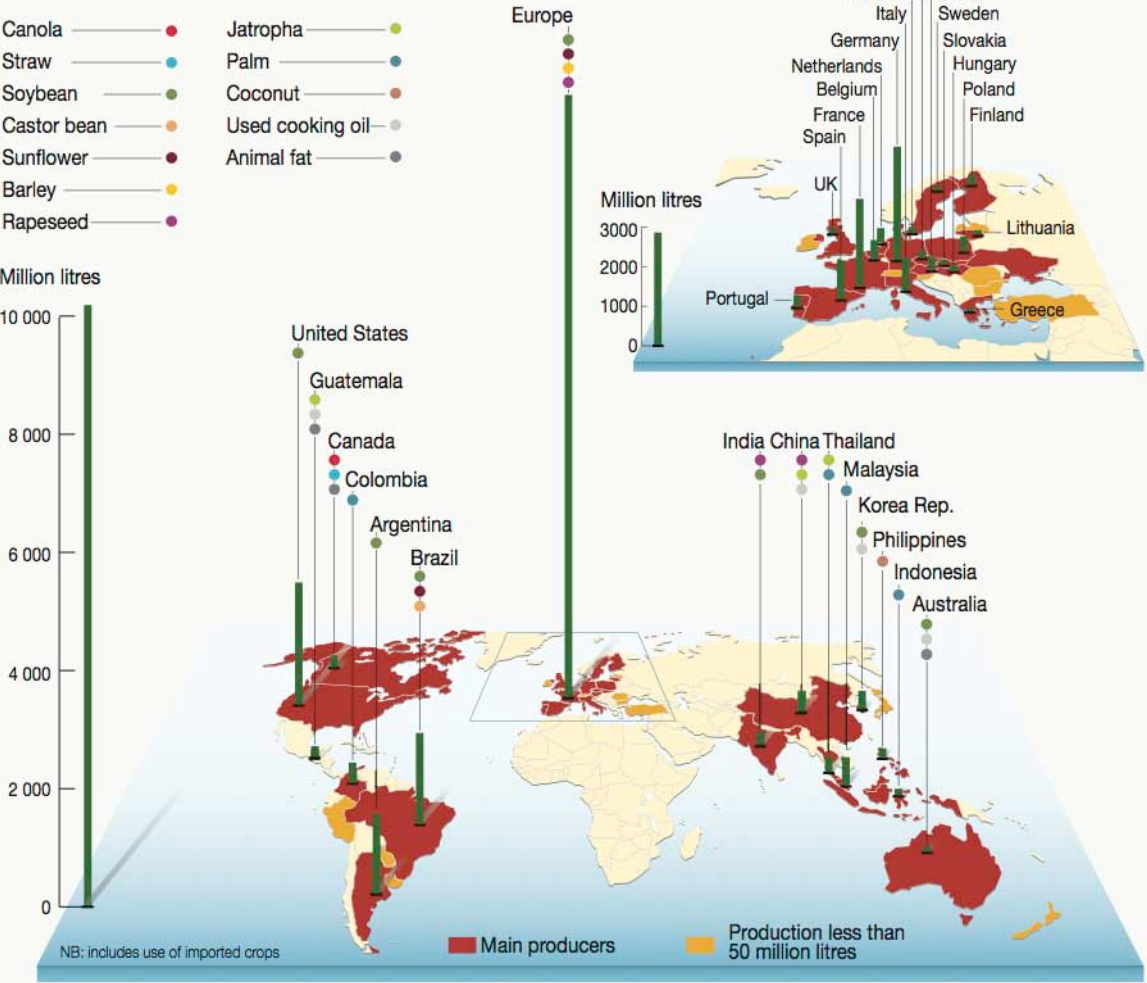


Figure 2.5 Global ethanol production, 2009

Global biodiesel production, 2009



Sources: Biofuels Platform, Geographic distribution of bioethanol and biodiesel production in the world in 2008; IEA, Biofuels for transport, 2004; UNCTAD, The emerging biofuels market, 2006; International Food & Agricultural Trade Policy Council, WTO disciplines and biofuels, 2006.

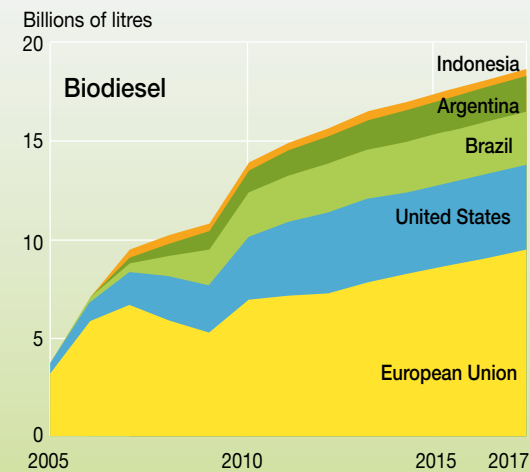
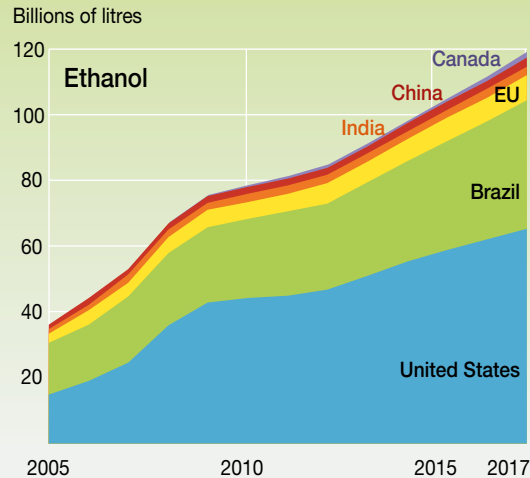
Figure 2.6 Global biodiesel production, 2009

Production trends indicate that the supply of both ethanol and biodiesel is steadily increasing, although the global ethanol market is more than four times larger than the global biodiesel market. Markets for both are increasing, not only in established, traditional markets such as the European Union, Brazil and the United States, but also in countries such as China, India and Argentina.

Production trends...

The latter countries are beginning to see the economic potential of the biofuel sector, and its prospective role in a green economy. Although markets are increasing, the global bioenergy potential is largely underused, particularly in some regions where there is significant potential for efficiency gains in both agricultural production and conversion to biofuels.

World biofuels production trends



Source: FAPRI, U.S. and World Agricultural Outlook, 2008.

Figure 2.7 World biofuels production trends

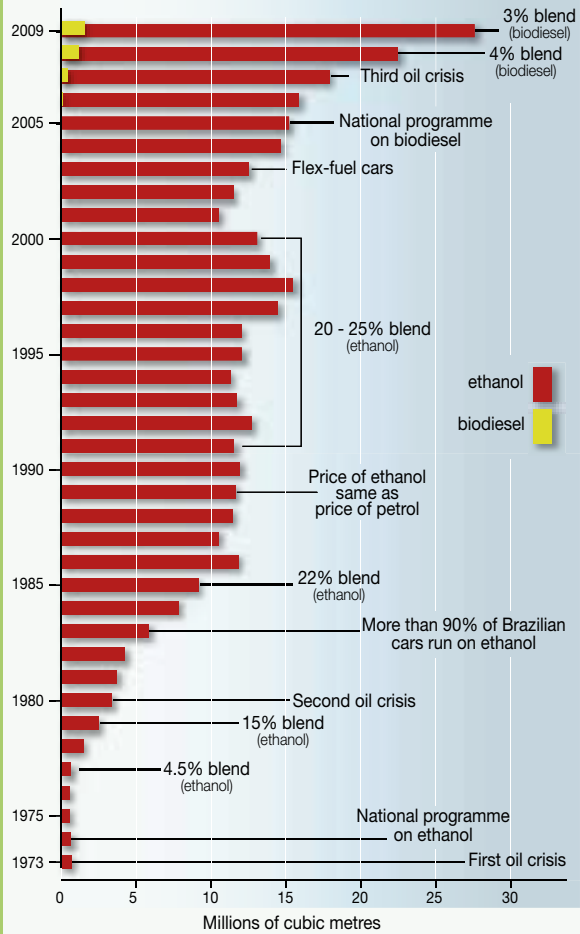
Box 2.1 Brazil: empowering an industry sector

Brazil has gradually developed and established an ethanol industry and growing biodiesel sector, offering an example of how countries can develop 'home-grown' renewable energy sectors. This development has been facilitated by long-term policies to address the entire supply chain, including the introduction of 'flex-fuel' vehicles which run on any blend of petrol and ethanol.

Social and environmental safeguards were developed to address concerns as they arose. The Social Fuel Seal, for example, encourages the economic integration of rural farmers into the biofuel sector, while land zoning provides a methodology for identifying suitable land areas for biofuel production without encroaching on land with high biodiversity. Efficiency improvements and integrated food energy systems (IFES) with sugarcane bagasse have also increased the productivity and efficiency of biofuels in Brazil. Finally, bagasse is increasingly used not only to supply the process energy for ethanol production plants, but also to supply electricity to communities near the plants.

Source: IEA (2010). Sustainable Production of Second Generation Biofuels www.iea.org/papers/2010/second_generation_biofuels.pdf. Le Monde Diplomatique (April, 2009) Brazil: who gets the cake?. Reuters (2009) Brazil Must Save Forests in Ethanol Push: Clinton <http://www.reuters.com/article/idUSTRE55123020090602>

Key factors of the Brazilian biofuel sector



Sources: Brazilian Government, Department for Agriculture, *Anuário Estatístico de Agroenergia*, 2009; Brazilian Oil Agency (ANP), online database.

Figure 2.8 Key factors of the Brazilian biofuel sector

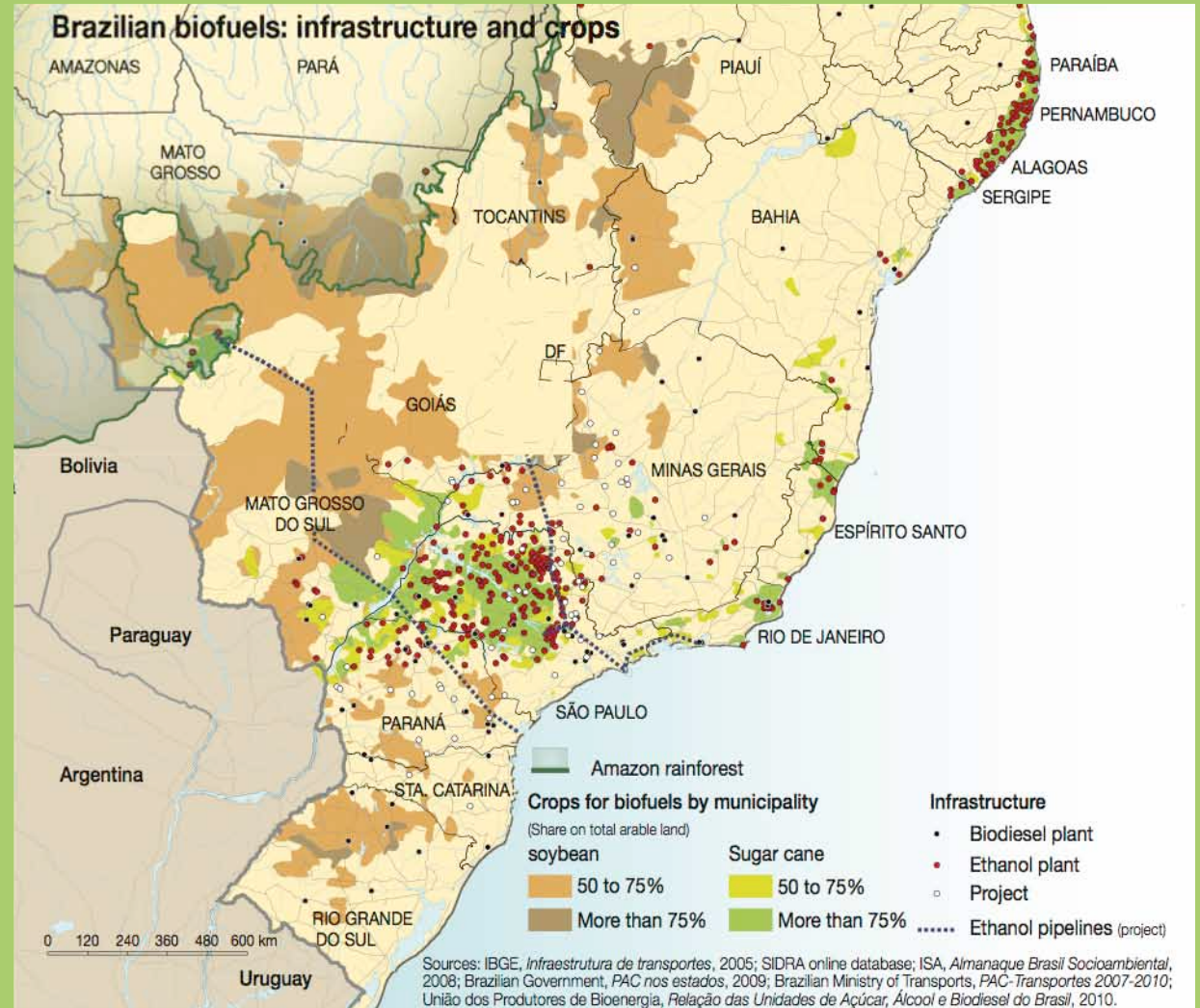


Figure 2.9 Brazilian biofuels: infrastructure and crops

Safeguards.

Biofuels pose several environmental and social risks. Therefore, to be truly a part of the green economy, biofuels need to comply with a set of safeguards along the entire production chain. Any bioenergy development strategy must integrate such safeguards at all levels, from policy to investments and the project itself. Achieving this will contribute to:

- sustainable management of natural resources, allowing for long-term use and resilience of the sector's development;

- managing reputational risk which may severely impact the sector's growth; and,
- avoidance of unintended consequences.

Such safeguards ultimately enhance the acceptability and competitiveness of the bioenergy sector.

Technically achievable potential must be matched with a comprehensive assessment of sustainable – socially and environmentally desirable – potential.

The good news is that integrated planning and management of key concerns can minimise risks

and create additional opportunities. Furthermore, it should be possible to gradually bridge the difference between the technical and the sustainable potential of biofuels by further implementing best agricultural practices and developing better technologies.

To date, safeguards have mainly concentrated on GHG balances of various feedstocks, conversion processes, and end-use chains (pathways). Biodiversity and water impacts, however, have received relatively little attention.

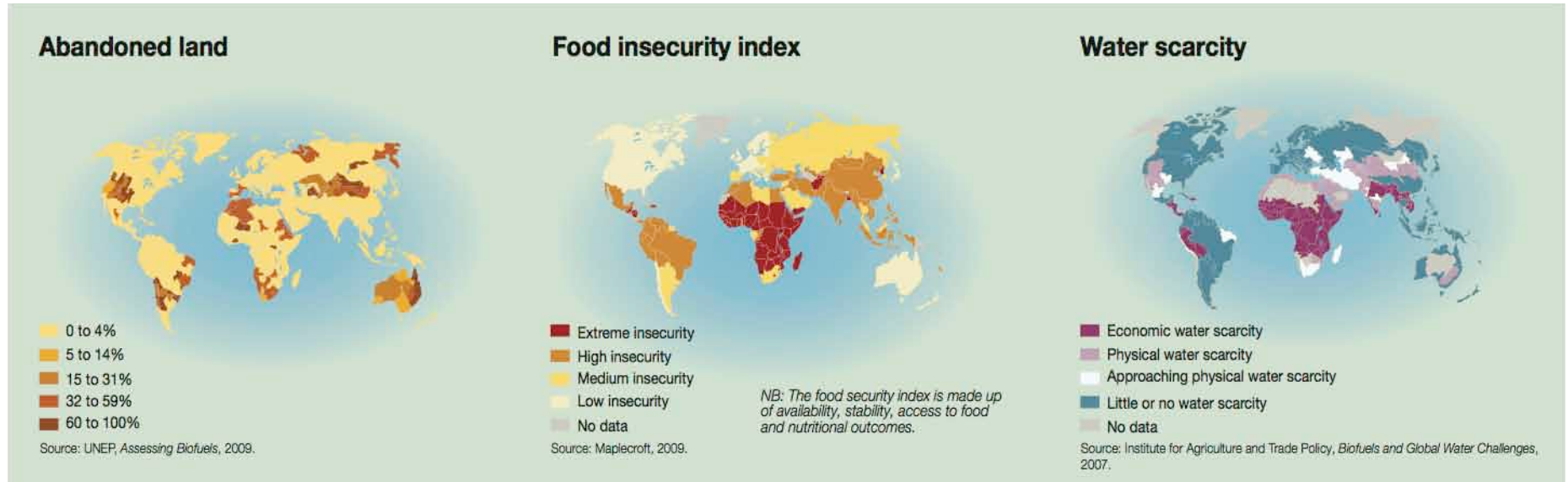
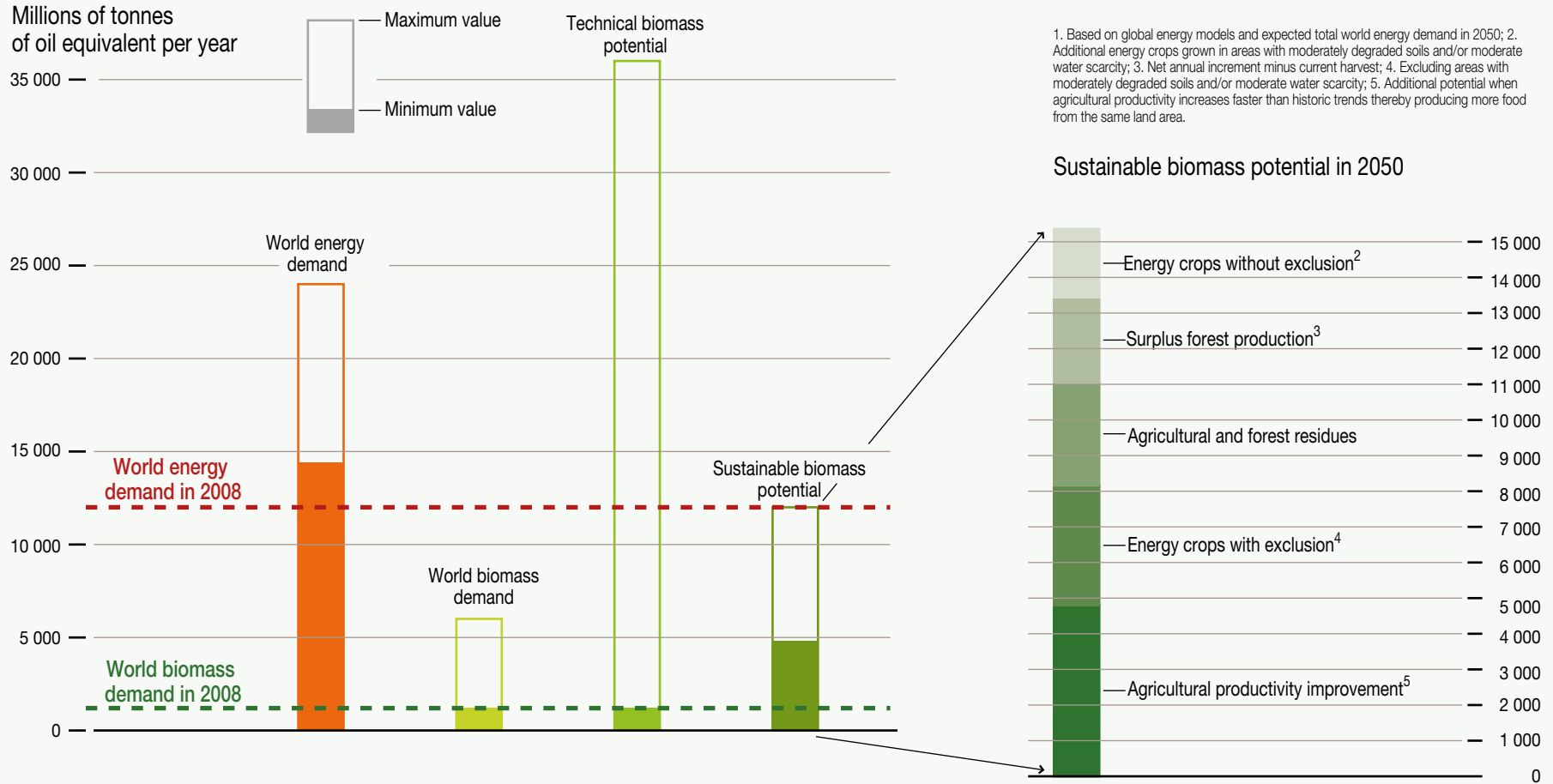


Figure 3.1 Abandoned land, Food insecurity index, Water scarcity

Technical and sustainable biomass supply potentials and expected demand for biomass in 2050 (primary energy)¹



Source: A Bauen *et al.*, "Bioenergy - a Sustainable and Reliable Energy Source", IEA Bioenergy, 2009 adapted from Dornburg *et al.*, Biomass assessment: Assessment of global biomass potentials and their links to food, water, biodiversity, energy demand and economy, 2008.

Figure 3.2 Technical and sustainable biomass supply potentials and expected demand for biomass in 2050 (primary energy)

As impacts can be significant, they need to be assessed from a number of angles, including:

- Direct and indirect land-use changes, with potential impacts on GHG emissions and biodiversity (Figure 3.3);
- Food security, water quality and availability.

Although some biofuels may be considered energy-efficient in their production and use, they can still be detrimental to biodiversity, water quality or social development. In some instances, the complete opposite may be true – an energy-inefficient biofuel might have substantially less social and environmental impacts. Consequently, all factors and trade-offs need to be assessed when developing safeguards.

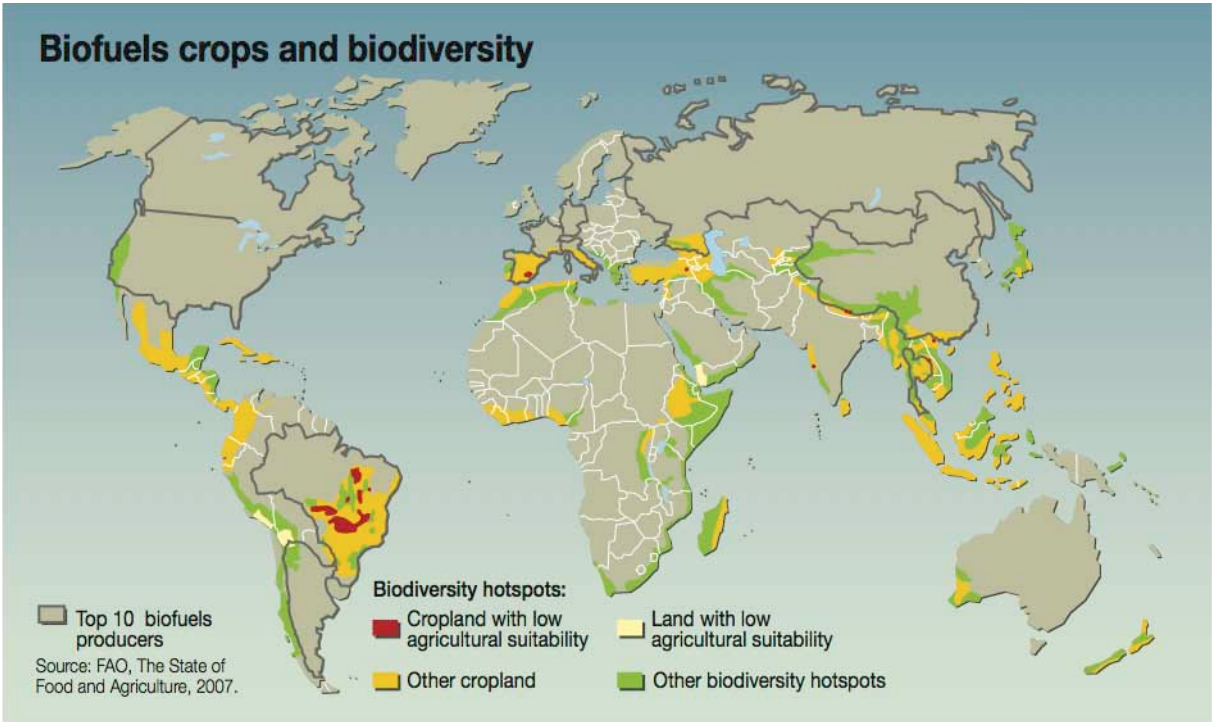


Figure 3.3 Biofuels crops and biodiversity

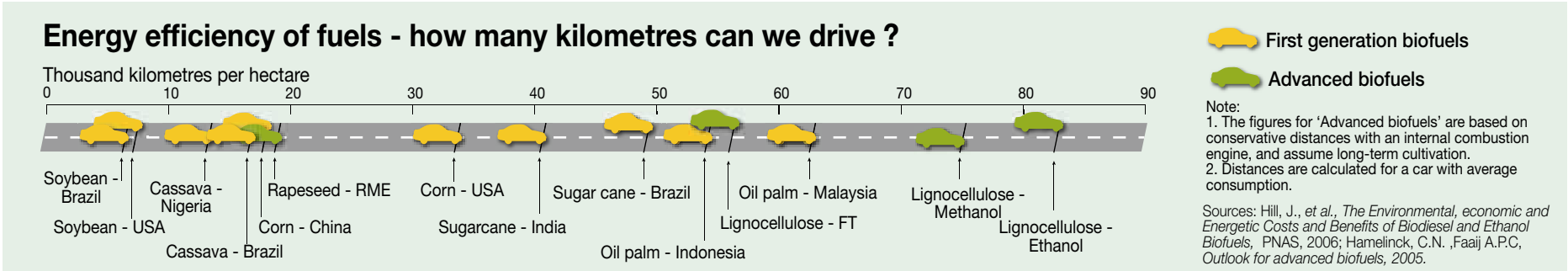


Figure 3.4 Energy efficiency of fuels – how many kilometres can we drive?

LAND.

Land is a critical, and potentially limiting factor for the biofuels sector.² The area of land currently used for biofuels production is small, but it has increased many times over in recent years. Land is a steadily declining resource globally. As the world population grows and climate change fluctuations increase (e.g. changes in temperature and rainfall patterns, and frequency and magnitude of extreme events) the demand for land will continue to grow. Furthermore, as developing countries develop economically, demand for food will rise and diets are expected to change to a more energy-intensive, animal-based diet. Crop yields are only just keeping pace, with bioenergy just one of many competing demands.

The question that needs to be asked at the outset of any biofuels development is straightforward: what is the best way to use a hectare of land? Unfortunately, there is no generic response, with the answer depending on the conditions prevailing in a given country as well as trade-offs between policy objectives.

2. The issue of land is not unique to biofuels, but important for all sectors that depend on land resources.

Energy input-output differs greatly between different feedstocks and fuels depending on local variables and production practices.

Land is a critical, and potentially limiting factor for the biofuels sector...

The energy gain from biofuels is often expressed as a ratio of biofuel energy output to fossil energy input. However, when considering which biofuels are the most efficient using this metric, allowance must also be made for whether or not co-products such as animal feed and other forms of energy or biomass production are involved. Economically, the value of co-products is also critical; and together with various subsidies and tax incentives associated with ethanol and biodiesel, should also be part of an economic feasibility study of biofuels production. The various uses of biomass (food and materials) are also a key factor; and local traditions and practices need to be taken into account.

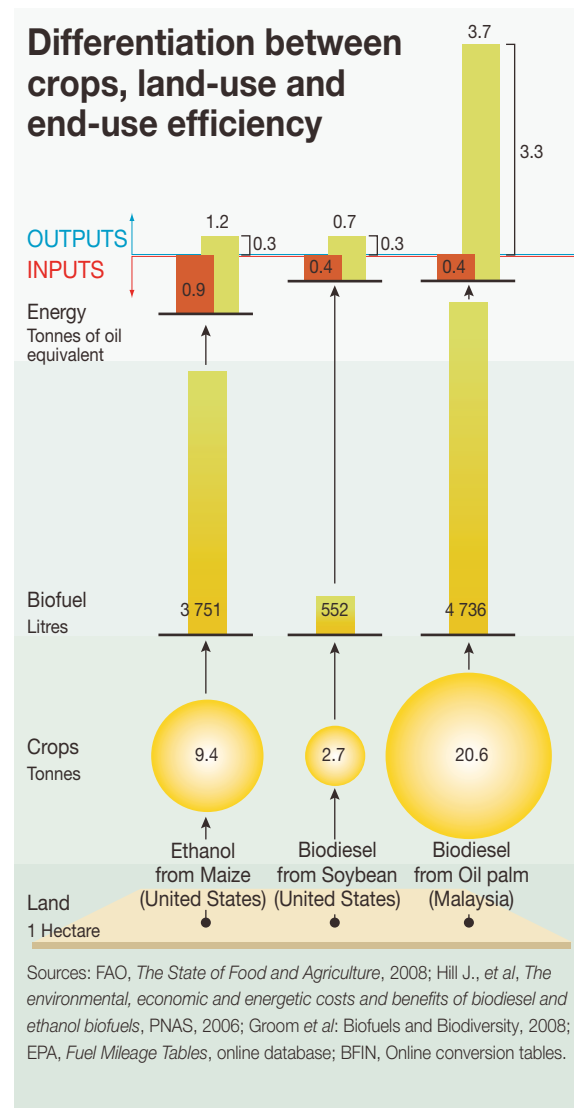


Figure 3.1.1 Differentiation between crops, land-use and end-use efficiency

Biodiversity and land use

The importance of ecosystem services should not be overlooked. Reducing biodiversity can reduce ecosystem services, without which development is impossible, including biofuels development. Biodiversity impacts related to biofuels are determined by the type of land being converted, as well as by the type of feedstock used. The efficiency of crops determines the amount of land required. When assessing the sustainability of biofuels within the context of conservation, comparison questions are important. What else can the land be used for? One option might be conservation, whereas another

might be for a different production system. Which production system is the most suitable and efficient for the land being used? Here, the land-use and end-use efficiency correlation is an interesting aspect when seeking to determine the overall energy output of a specific biofuel. This type of data can help determine which type of biofuels will use land most efficiently, reducing pressure on natural ecosystems.

Figure 3.1.2, for example, shows the differences in land requirements by fuel type. The graphic compares different liquid biofuels and alternative drive systems such as an electric vehicle running on electricity produced from wind power.

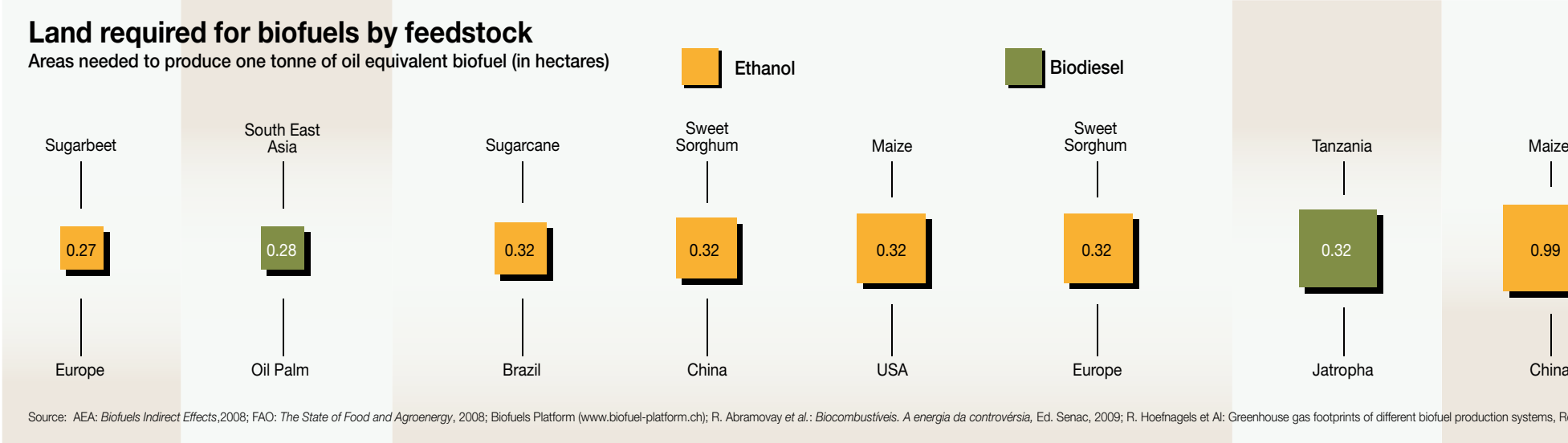
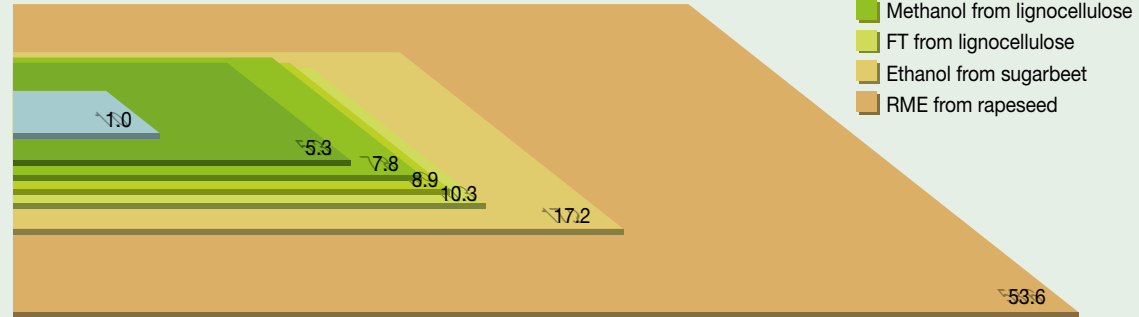


Figure 3.1.2 Land required for biofuels by feedstock

Land required to drive 100 kilometres

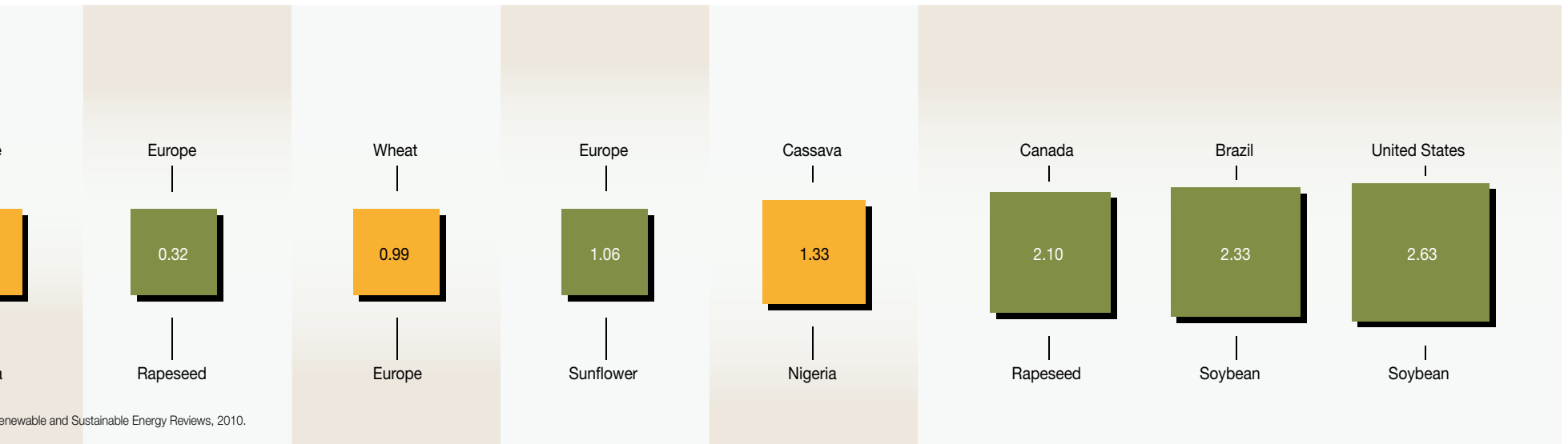
Square metres



NB: Data assumes the use of fuel-cell vehicles, with conservative estimates for long-term cultivation for each crop.

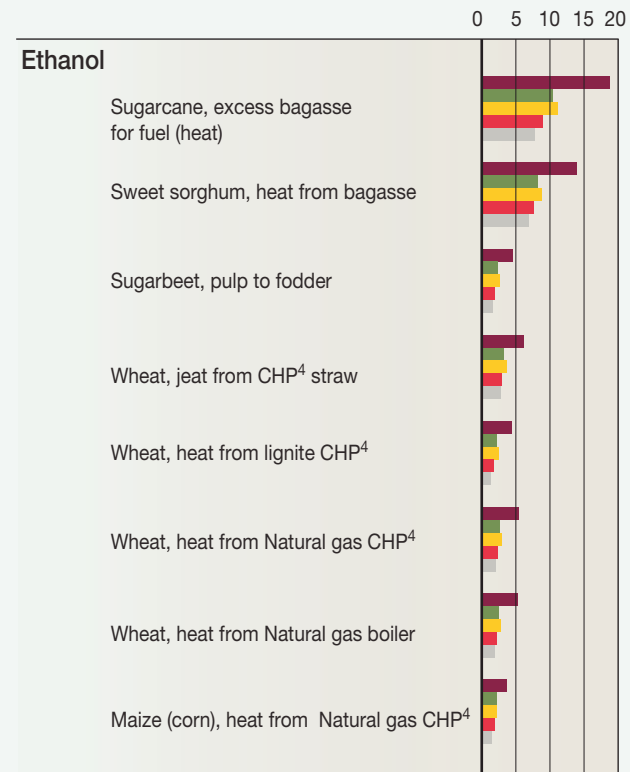
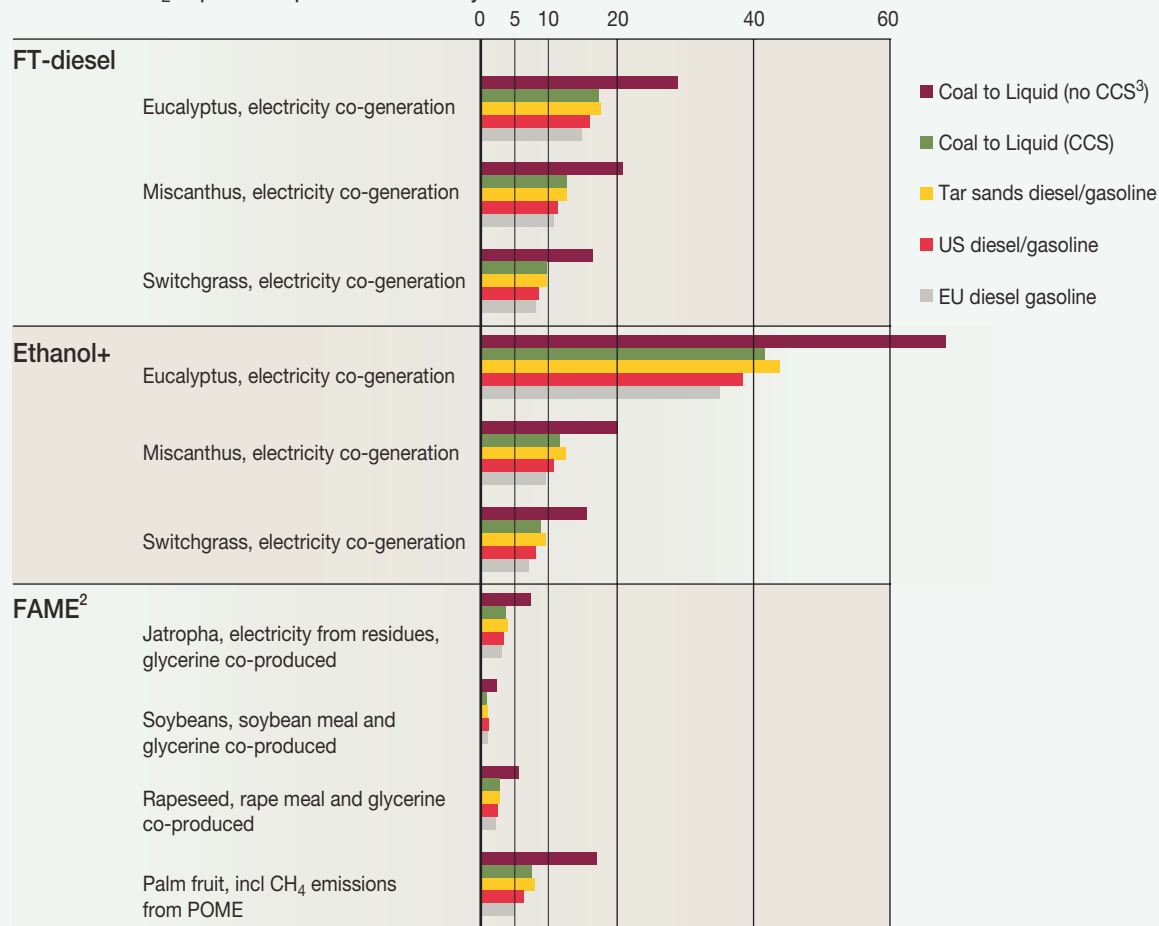
Sources: Hamelinck, C. N. and Faaij, A. P., *Outlook for advanced biofuels*, Elsevier, 2005; University of Groningen, *Effective Land Use for Renewable Energy Sources*, 2009

Figure 3.1.3 Land required to drive 100 kilometres



Savings in greenhouse gas emissions by fuel type¹

Tonnes of CO₂ equivalent per hectare and year



Notes: 1. Allocation of co-products by EU default (energy allocation for co-products, subtraction for co-generation of electricity and heat), energy, mass and market value 2. Fatty-acid methyl esters. 3. Carbon capture and storage. 4. Combined heat and power.

Source: R. Hoefnagels et al, Greenhouse gas footprints of different biofuel production systems, Renewable and Sustainable Energy Reviews, 2010.

Figure 3.1.4 Savings in greenhouse gas emissions by fuel type

Land conversion and greenhouse gas emissions

The conversion of high carbon-storage ecosystems, such as tropical forest, savannah and peatland into biofuel plants, can neutralise any GHG emission reductions achieved by replacing fossil fuels with biofuels, and even lead to a net increase in CO₂ emissions.

Biofuels, in the use phase, emit the carbon that has been previously absorbed during plant growth. Inputs during cultivation and conversion need to be accounted for. However, the bulk of GHG emissions are related to land-use change. The carbon footprint varies considerably depending on the type of land converted, the type and yield of the feedstock (tonnes per hectare), as Figure 3.1.4 shows. It is therefore key that any GHG analysis takes into account the entire life-cycle of biofuels, including impacts from land-use change. As illustrated, these CO₂ emissions range across different types of land and crops (Figure 3.1.5).

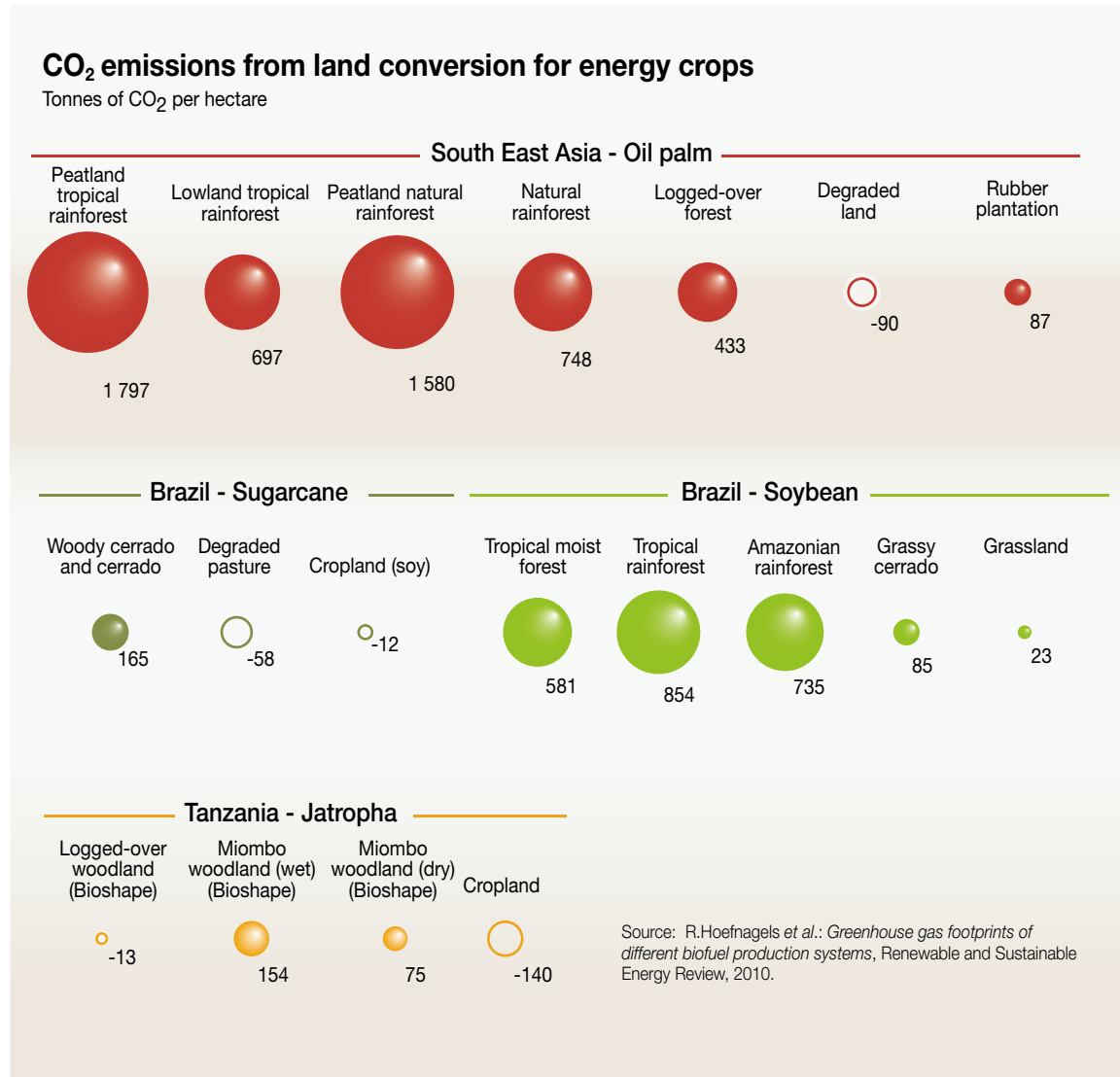


Figure 3.1.5 CO₂ emissions from land conversion for energy crops

Ecosystem carbon payback time

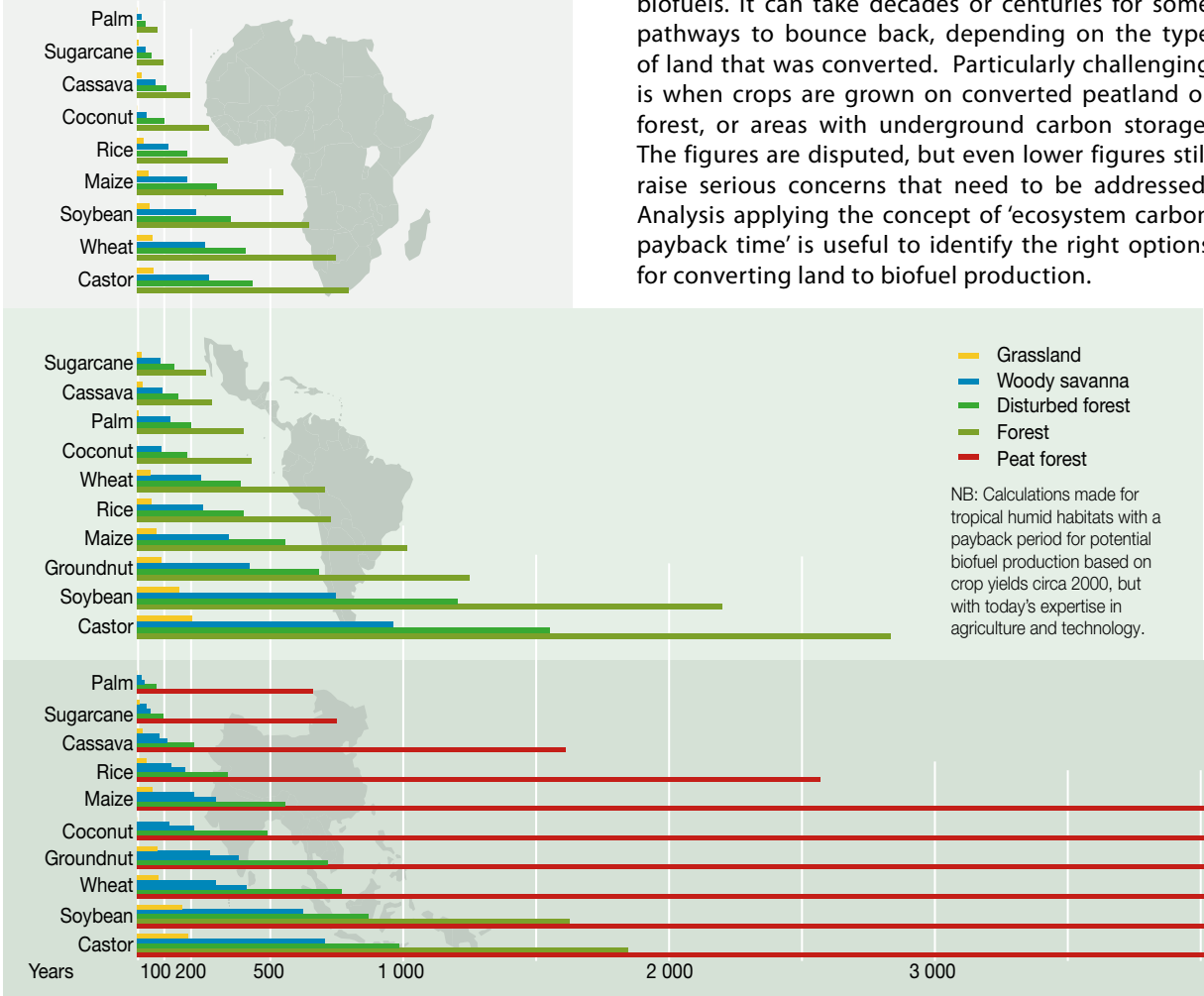


Figure 3.1.6 Ecosystem carbon payback time

The ‘carbon debt’ of biofuels on the other hand, is the number of years it can take to offset the carbon emissions generated by converting land for biofuels. It can take decades or centuries for some pathways to bounce back, depending on the type of land that was converted. Particularly challenging is when crops are grown on converted peatland or forest, or areas with underground carbon storage. The figures are disputed, but even lower figures still raise serious concerns that need to be addressed. Analysis applying the concept of ‘ecosystem carbon payback time’ is useful to identify the right options for converting land to biofuel production.

Indirect land-use change induced by increased biofuels production

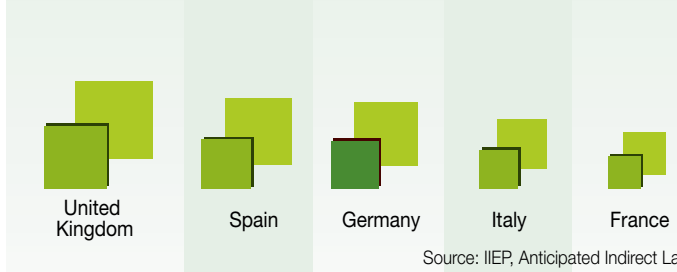
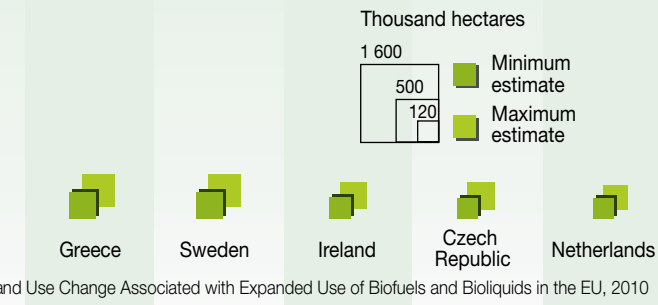


Figure 3.1.7 Indirect land-use change induced by increased biofuels production

Demand development

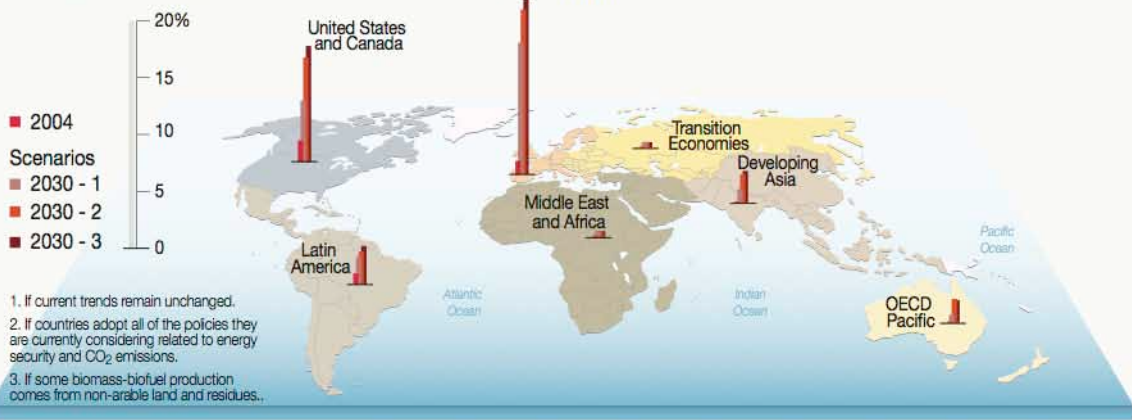
Figure 3.1.7 indicates land requirements for biofuels production in response to current biofuels mandates. Depending on projected biofuels demand and available arable land, additional land requirements may exceed a nation’s own resources, and hence have a spill-over effect on other countries and regions.

Increased biofuels production



Land requirements for biofuels production

Percentage of arable land



Source: FAO, *Climate change, biofuels and land*, 2006.

Figure 3.1.8 Land requirements for biofuels production

For example, studies indicate that most European countries will not have sufficient available land resources to produce the feedstocks required to comply with the blending mandates prescribed in the European Renewables Directive themselves. In the case of Germany, it is projected that by 2030 an estimated 10-11 million hectares of agricultural land would be needed to produce the biomass to comply with the biofuels blending mandate. Given current land use, the majority of that land would be outside Germany and most feedstock imported, such as palm oil from Indonesia and soy from Brazil.

The Food and Agriculture Organisation estimates that that growth in biofuels production from 2004 levels to 2030 will require 35 million hectares of land, an area approximately equal to the combined area of France and Spain. Taking 2004 as its baseline Figure 3.1.8 outlines some scenarios for land requirements. Scenario 1 reflects business as usual, scenario 2 plots an alternative policy under which countries adopt carbon commitments, and scenario 3 follows a second-generation biofuels case.

Given these land constraints, the expanding biofuels industry is likely to lead to conversion of land. If no safeguards are applied or they are inadequate, converting land for biofuels may have negative consequences, depending on the type and the amount of land converted. The effects of land-use change may be direct (LUC) or indirect (iLUC).

For example, converting pasture, forest, grassland, peatland and wetland for biofuel feedstock production fall under the LUC category, the land cover and use being adapted. But when biofuel-feedstock production replaces other agricultural production, such as food, feed or fibre, and encroaches on natural land this counts as iLUC. This is also referred to as 'leakage' or a 'domino effect'. Key risks from both direct and indirect land-use changes include higher GHG emissions, lower food security and loss of biodiversity – loss of ecosystem services, resources and processes that are supplied by natural ecosystems.

Ensuring that growing biofuel feedstock does not have an adverse ecological impact in third countries has become a priority concern. The EU and several countries have, for example, introduced various sustainability measures enforced for example through certification schemes. It remains to be seen whether certification can deliver the required monitoring and enforcement of more sustainable practices over a long and complex supply chain.

Food Security

Biofuels have been criticised for causing food insecurity, but many other factors often play a far more significant role than biofuels. But rapid, large-scale growth in biofuel production without sufficient safeguards does pose a risk for food security. This risk needs to be seen in the context of population growth, changing diets, slowing crop-yield improvements, and climate-change impacts on agriculture.

While much has been said about the risks, little has been said about the opportunities which biofuels can bring to food security with appropriate policies

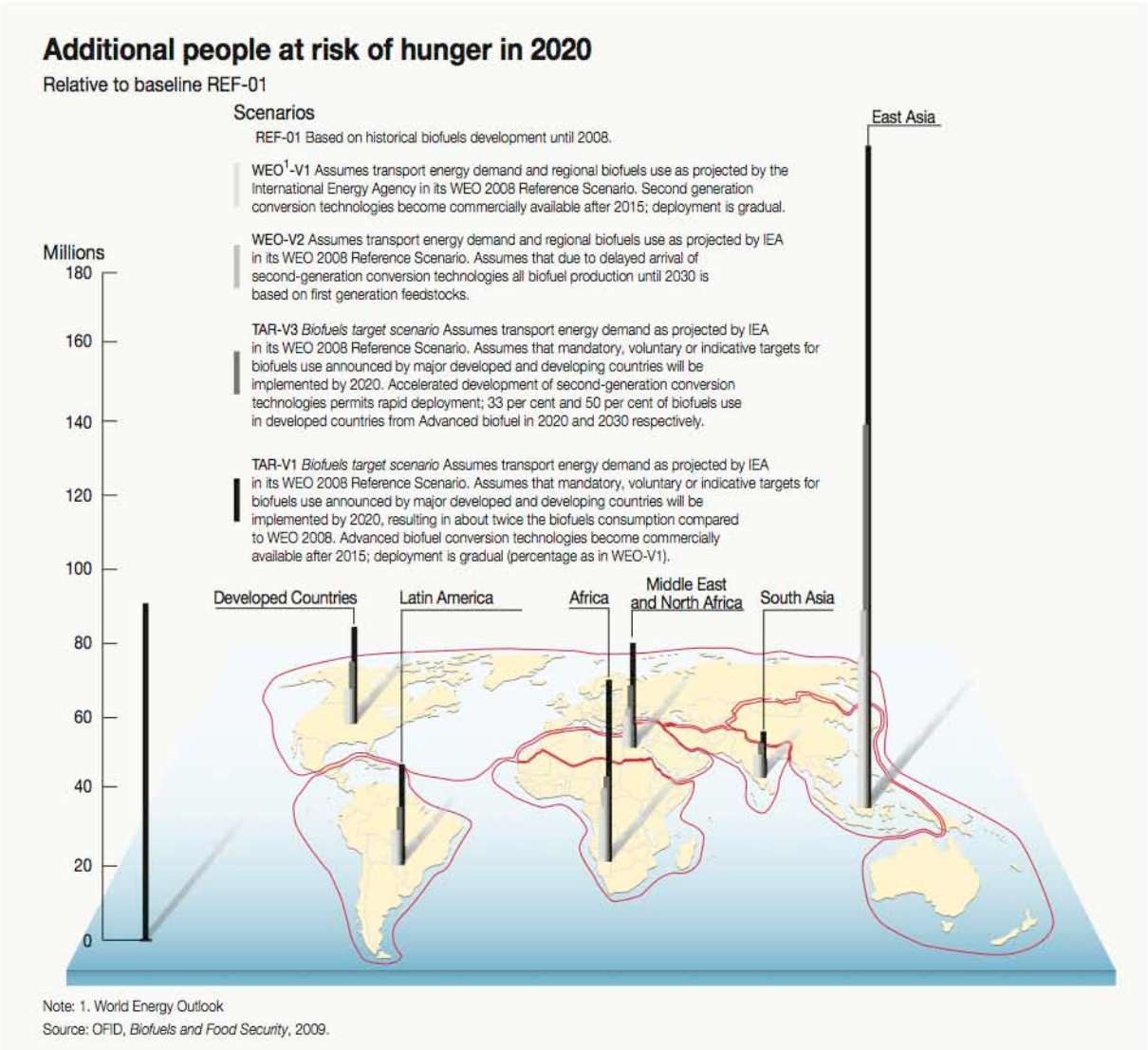


Figure 3.1.9 Additional people at risk of hunger in 2020

and industrial commitments. Biofuels can increase food security when the necessary investment and technology improves overall agricultural productivity and subsequently food availability. While higher food prices may reduce its accessibility, biofuels can improve local economies and hence improve the ability to purchase food.

availability...

New infrastructure built to support a developing biofuels sector, can improve access to markets in various industry sectors, and thereby increase overall accessibility. Stability as well as food production and use can be improved through increased access to locally produced biofuels that allow, for instance, for crop drying, cooking and purification of drinking water.

accessibility...

The impacts of biofuels production on food security vary a great deal between communities, regions and countries. At a national level, food and energy exporters have a good chance of generating positive effects, whereas the outcome for those importing food and exporting energy resources, or vice versa, is likely to be fairly neutral. Net importers of both food and energy will require international support. Similarly at the local level, those who benefit from higher prices for crops may be able to balance higher food prices, in contrast to the urban poor who spend an already sizeable share of their income on food.

stability...

Figure 3.1.10 outlines possible scenarios for the impact of biofuels on agricultural prices and food security. Although there are several factors that affect agricultural prices, including seasonal variation, market speculation,

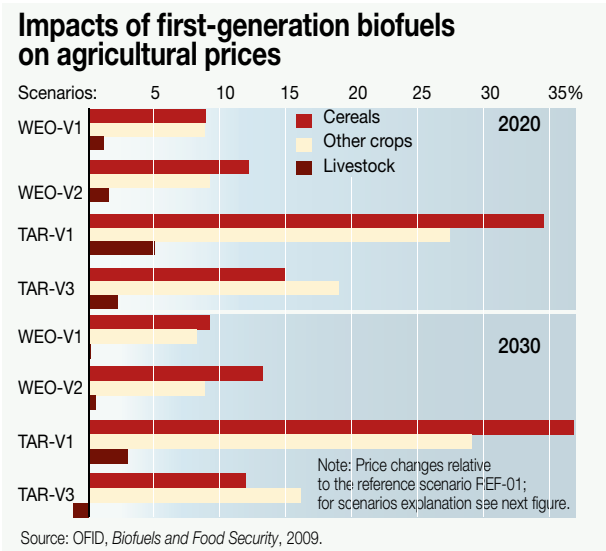


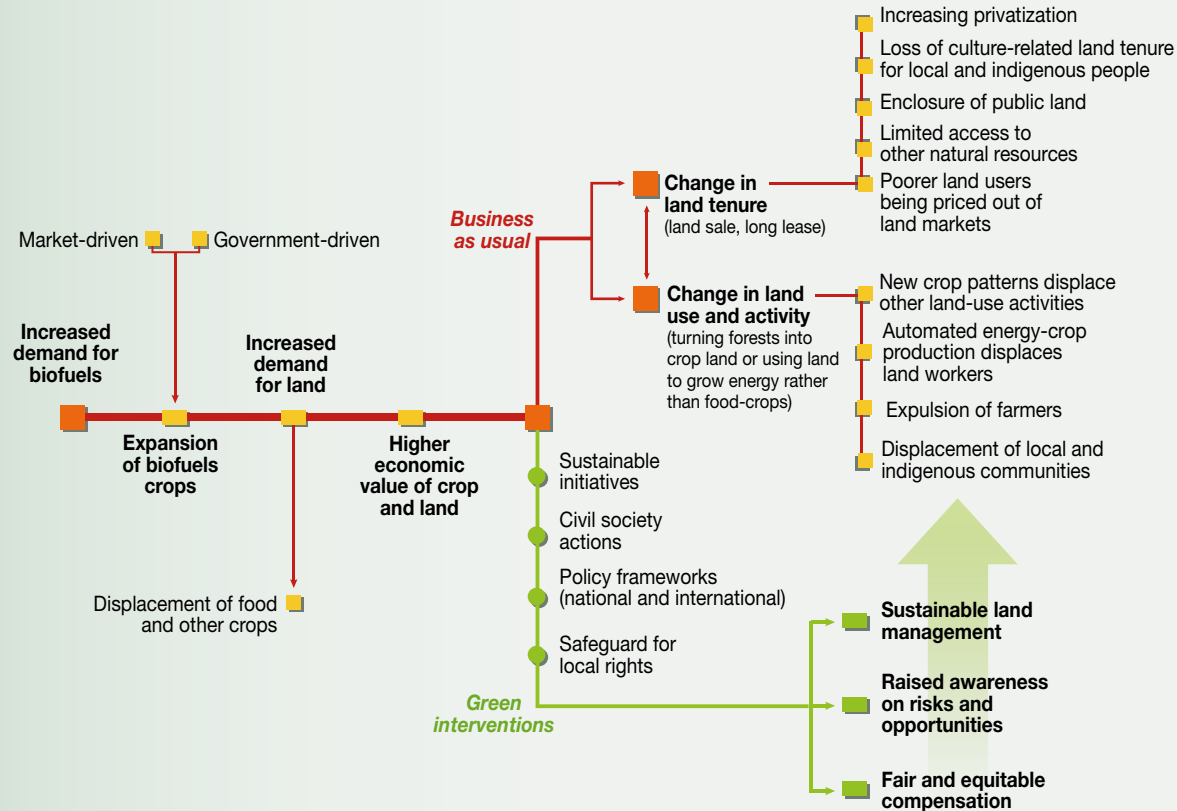
Figure 3.1.10 Impacts of first generation-biofuels on agricultural prices

and extreme weather patterns, some biofuel development scenarios indicate a relationship between agricultural prices and biofuel production. Here, the scenario projects that the largest price increase will be for cereals, with the introduction of first-generation biofuels triggering a price increase ranging from 8 percent to over 35 percent.

food utilisation...

Corn, for example, is a major biofuel feedstock in the US, as well as being a staple food crop in many South American and African countries. It is therefore likely that an increase in the market price for corn will have implications for food security in some regions. When the global market price of corn rose significantly in 2007 it had several implications for poor communities in Mexico for which corn is a staple food.

Potential risks of energy crop expansion on land access



Note: the diagram shows a generalized process for land access impacts. Effects might only occur in some regions and for some crops.

Source: Thomas Molony, T. and Smith J., *Biofuels, Food Security and Africa*, African Affairs, 2010; Cutula, et al., *Fuelling exclusion? The biofuels boom and poor people's access to land*, FAO, ILED, 2008; FAO, *Bioenergy and Food Security. The BEFS Analytical Framework*, 2010.

Land tenure

Poor land tenure security due to lack of appropriate rules and processes, and biofuels production encroaching on land used by pastoralists or for cultural purposes affect local livelihoods and access to land, particularly for poor rural people in developing countries. Figure 3.1.11 indicates various measures which should be taken to mitigate this risk.

Pragmatic approaches to reduce land use

The negative consequences of iLUC have been hotly debated. Recent debate has focused increasingly on a pragmatic approach to reducing the need for land, thereby reducing risks from direct and indirect changes in land use. These approaches include:

- Using degraded and/or underused land where the risks of increased GHGs and the loss of biodiversity would be substantially lower. However, the process for identifying such land areas needs to be thorough, addressing soil recovery issues and scope for higher levels of agrochemical and water input to increase yields.
- Using waste and residues, which requires a solid definition of waste and an assessment of competing uses, such as using organic residues to rebuild soil fertility.
- Improving yields, particularly in regions where crop and land productivity are considerably lower and could still be improved without incurring risks associated with intensive agriculture.

Figure 3.1.11 Potential risks of energy crop expansion on land access

Estimated feedstock efficiency and environmental impacts

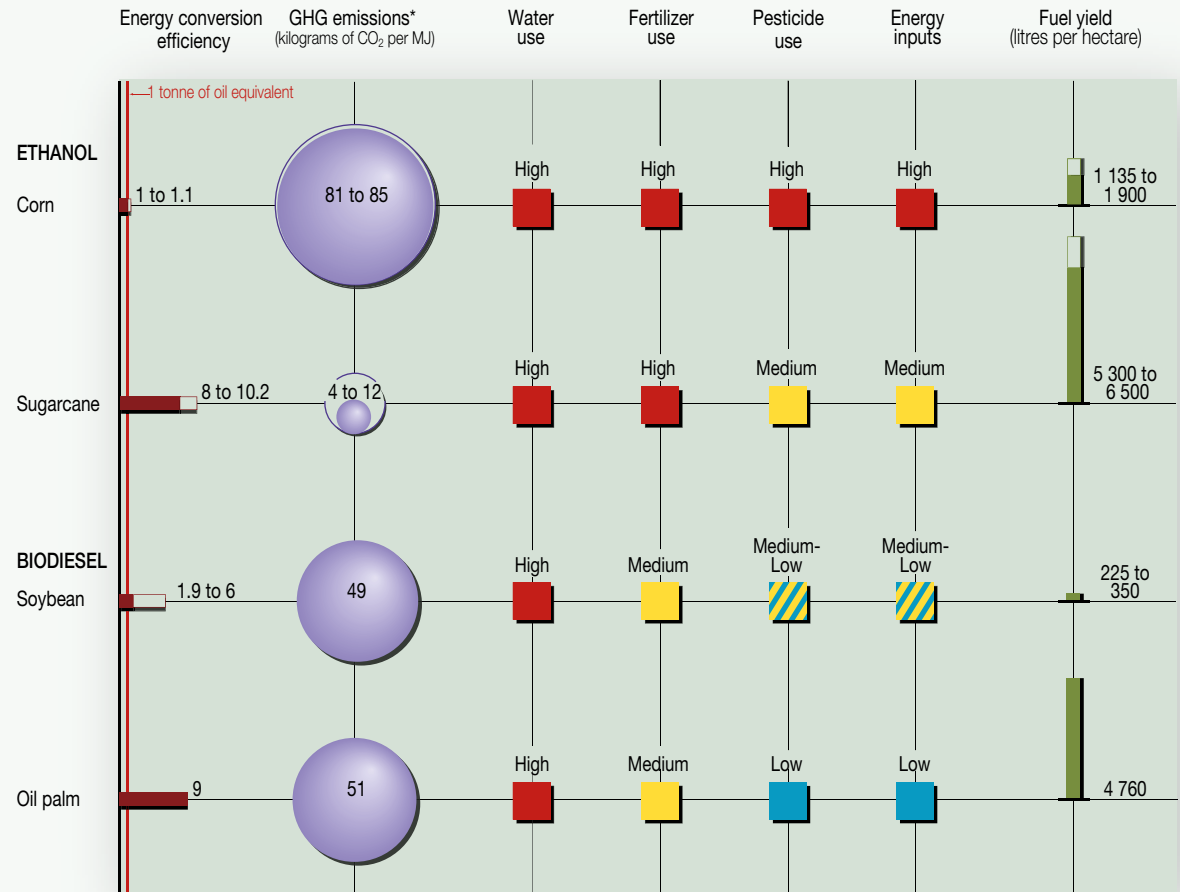


Figure 3.1.12 Estimated feedstock efficiency and environmental impacts

- Using an agricultural-systems approach, which integrates both biomass production for various end-uses and conservation measures. For example, one approach could be IFES designed to integrate, intensify and thus increase the simultaneous production of food and energy. Conservation agriculture is an approach for 'resource-saving agricultural crop production that strives to achieve acceptable profits together with high and sustained production levels while concurrently conserving the environment' (IFAD).
- Encouraging efficiency improvements in agricultural production to maximise output per unit of input.

Biodiversity.

Biodiversity is the basis for any development; it is the natural capital, the stock of natural ecosystems, which provide services for any human activity. As pointed out above, the main immediate threat to biodiversity from biofuel production is through changes in land use, but longer-term threats may come from the spread of invasive species and uncontrolled use of genetically modified (GM) organisms.

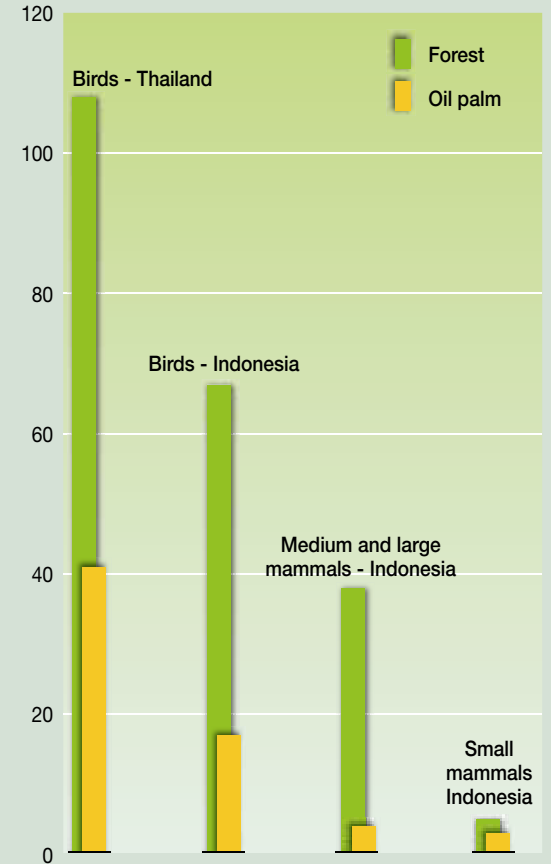
The environmental and social costs of losing ecosystem services can be substantial, with an

economic cost of billions of dollars, though often times the price of goods and services in the local and global economy often fails to reflect this cost. Land conversion, which leads to increased carbon emissions, further exacerbates the risk of losing ecosystem services, climate change being likely to lead to further changes in ecosystem services.

Biodiversity is the basis for any development...

Biodiversity in forests and oil palm plantations, South East Asia

Number of selected species recorded



Source: Danielsen, et al., *Biofuel Plantation on Forest Land, Double Jeopardy for Biodiversity and Climate*, 2008.

Figure 3.2.1 Biodiversity in forests and oil palm plantations, South East Asia

Value of ecosystem services

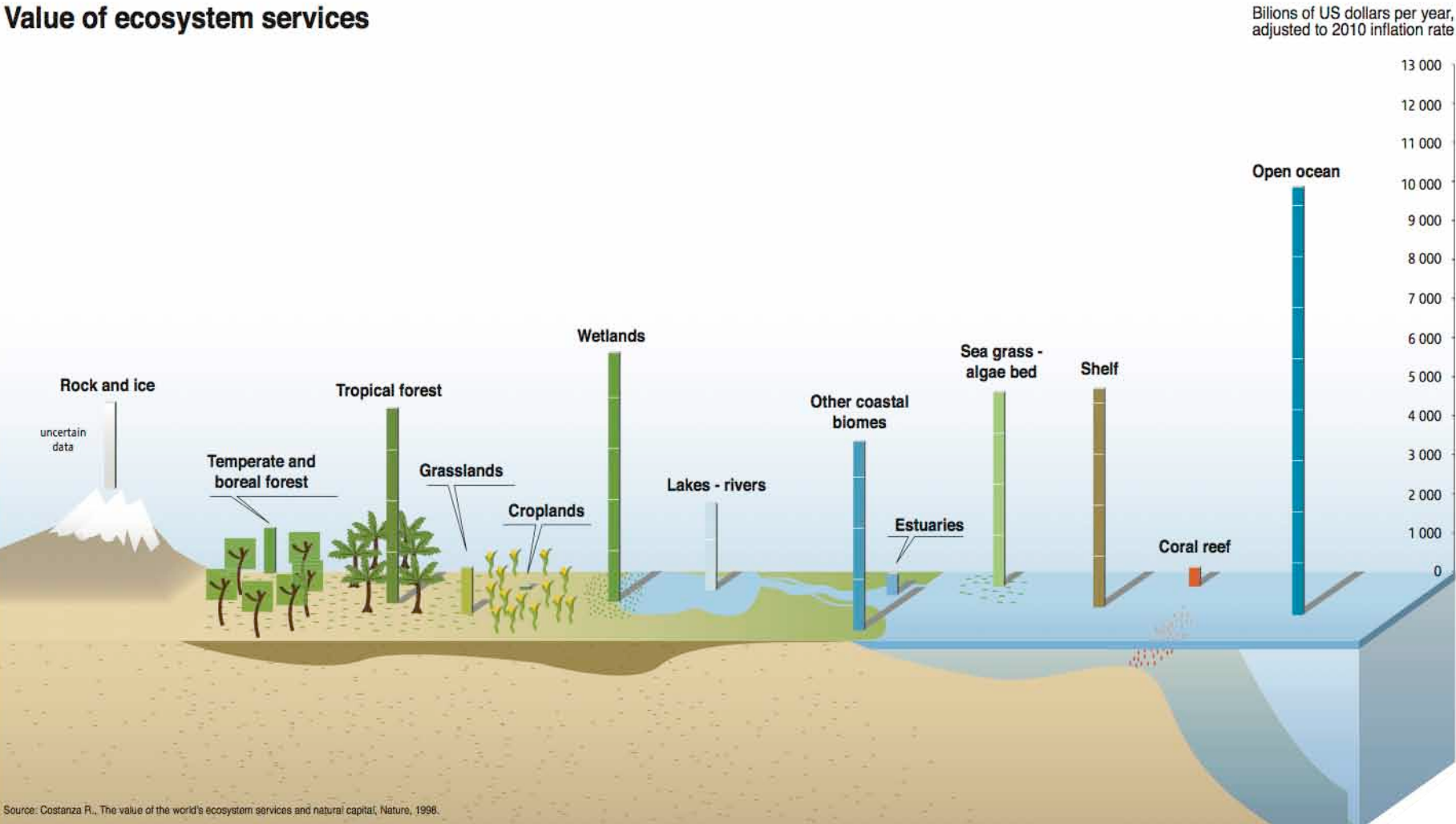


Figure 3.2.2 Value of ecosystem services

Estimated costs and benefits of restoration projects in different biomes

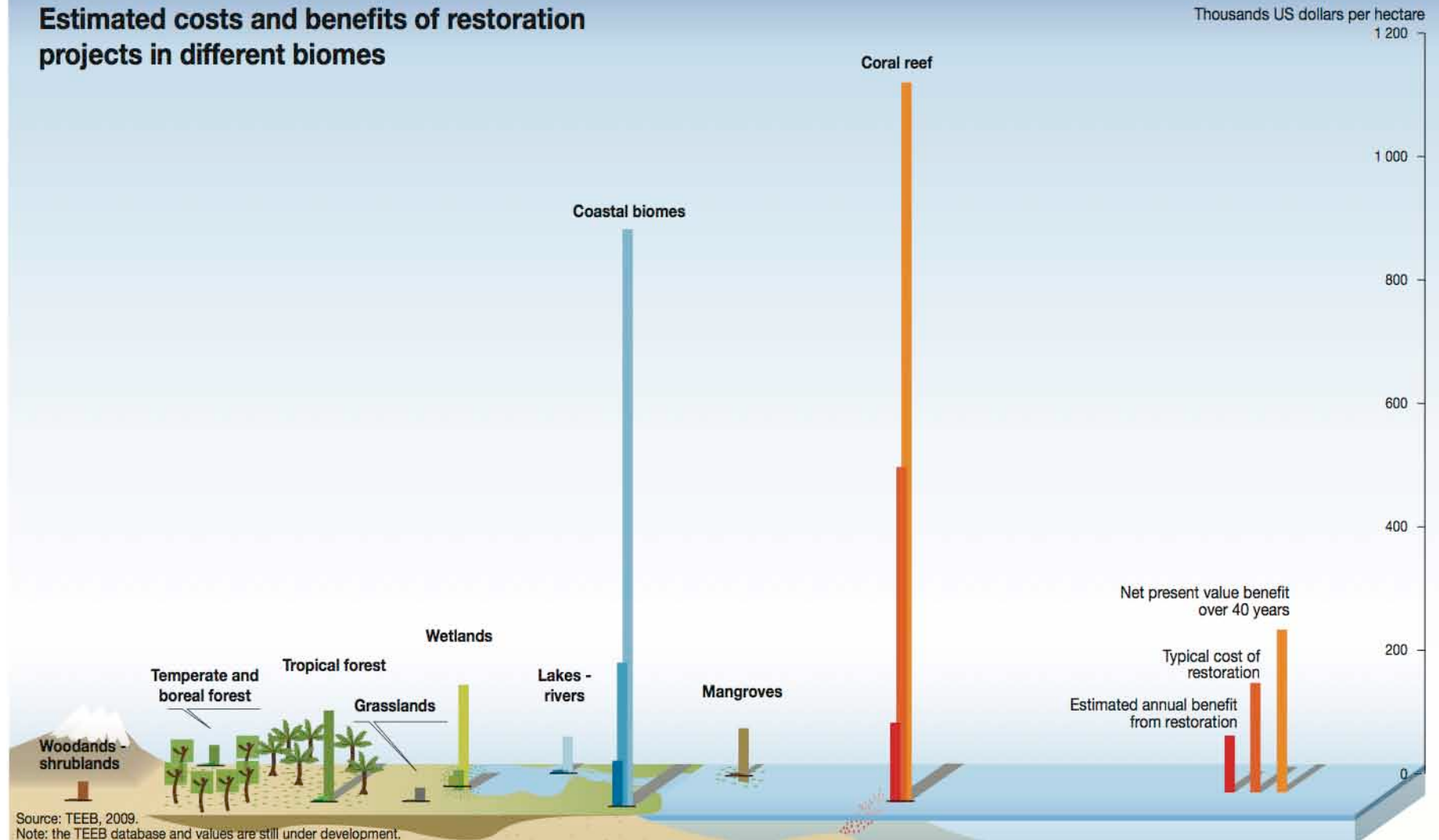


Figure 3.2.3 Estimated costs and benefits of restoration projects in different biomes

Biofuels production and forest area variation in selected countries

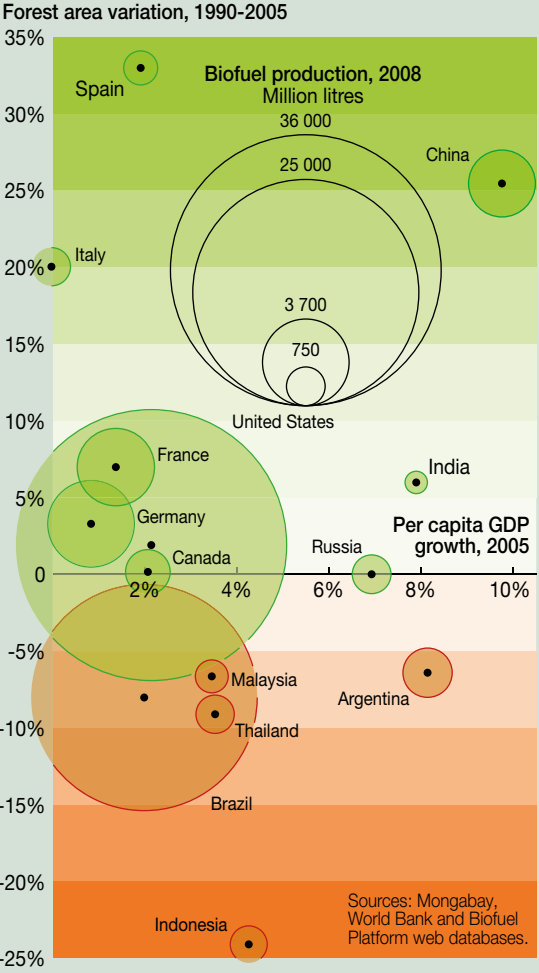


Figure 3.2.4 Biofuels production and forest area variation in selected countries

Impact of land conversion on biodiversity

Short-term impact of land conversion

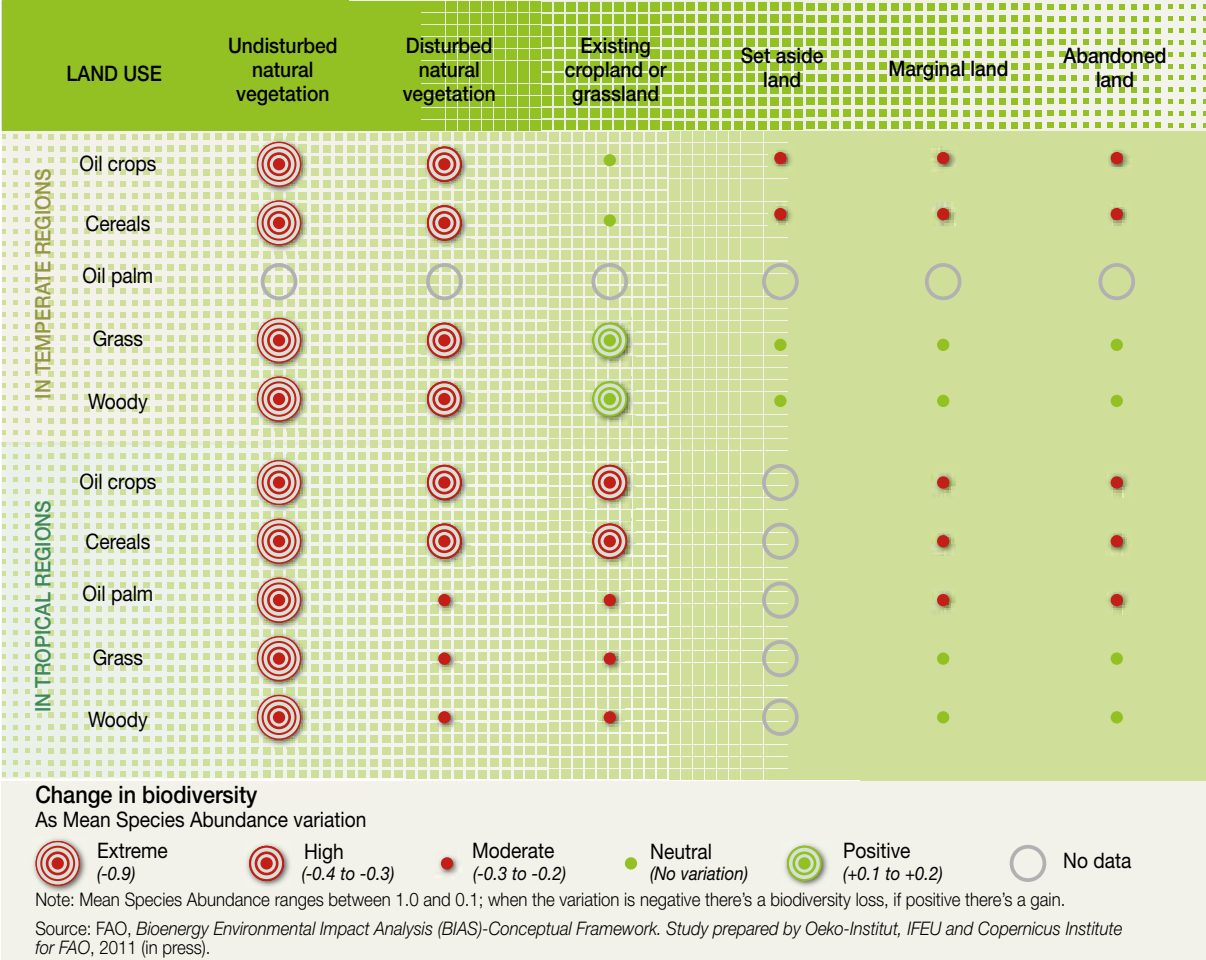


Figure 3.2.5 Impact of land conversion on biodiversity

Restoring ecosystems can, however, provide a good return on investment (Figure 3.2.3).

The impacts of land conversion on biodiversity may be significant. The degree of impact relates to many factors, including where and how the bioenergy product is cultivated. The short-term impacts of land conversion are represented in Figure 3.2.5.

Gains and losses in forest area vary globally, and the impact differs greatly between the various crops used for biofuels (Figure 3.2.4). Forest-cover is enhanced through afforestation or by natural expansion, and reduced either by deforestation or natural disasters which may prevent forest from naturally regenerating itself.

Forest degeneration is often caused by overexploitation of forest areas by humans, pests, disease or recurrent forest fires. Generally, this implies a change in the health and vitality of a forest ecosystem. Reduced forest cover entails increased carbon emissions. Henceforth payment for ecosystem services, which contribute to conservation or increased forest cover, offer a promising way of countering climate change.

Converting land for biofuel production can cause biodiversity impacts in the short-term, but such conversion also affects the future resilience of natural ecosystems. In an extreme case, complete deforestation reduces the ability of forestland to regenerate and absorb carbon in the future (Figure 3.2.6).

Many plant species currently considered for advanced biofuels are potentially invasive. Materialisation of invasiveness depends on the landscape, climate and the way they are introduced. Thorough assessment is needed before such species are introduced, as well as appropriate management systems applied to protect native ecosystems and ecosystem services.

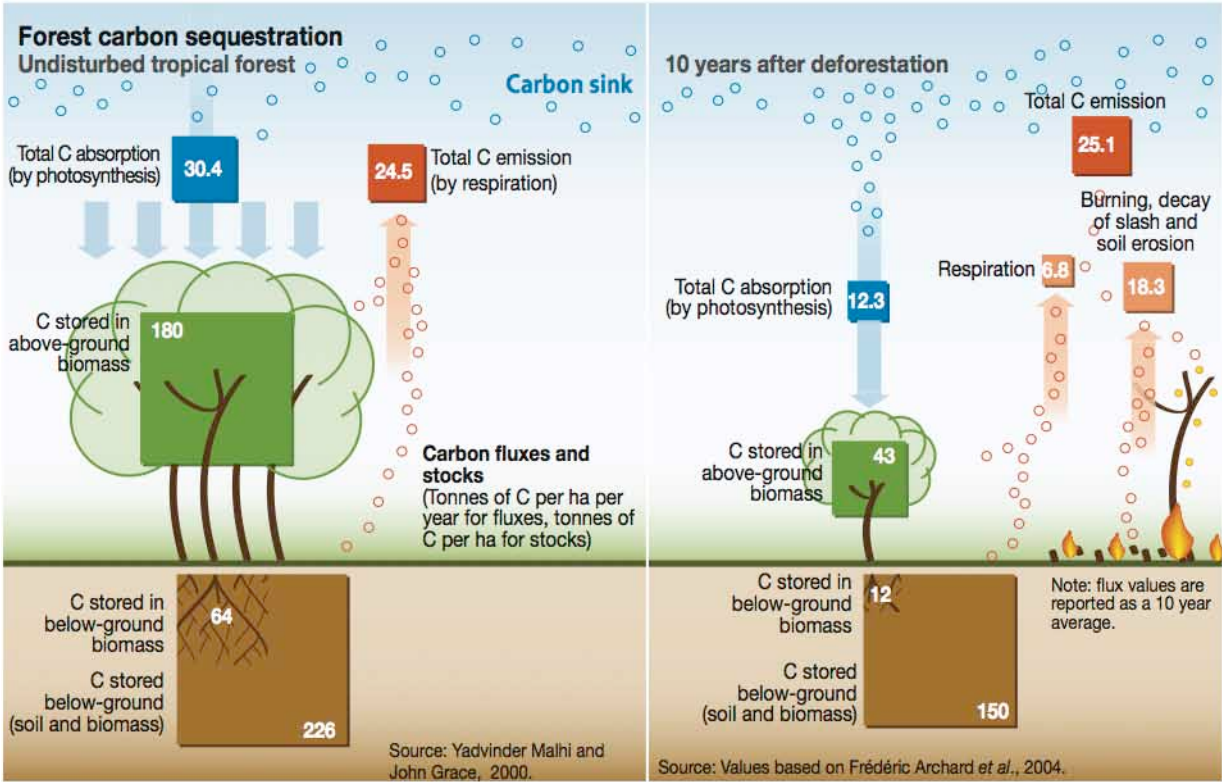


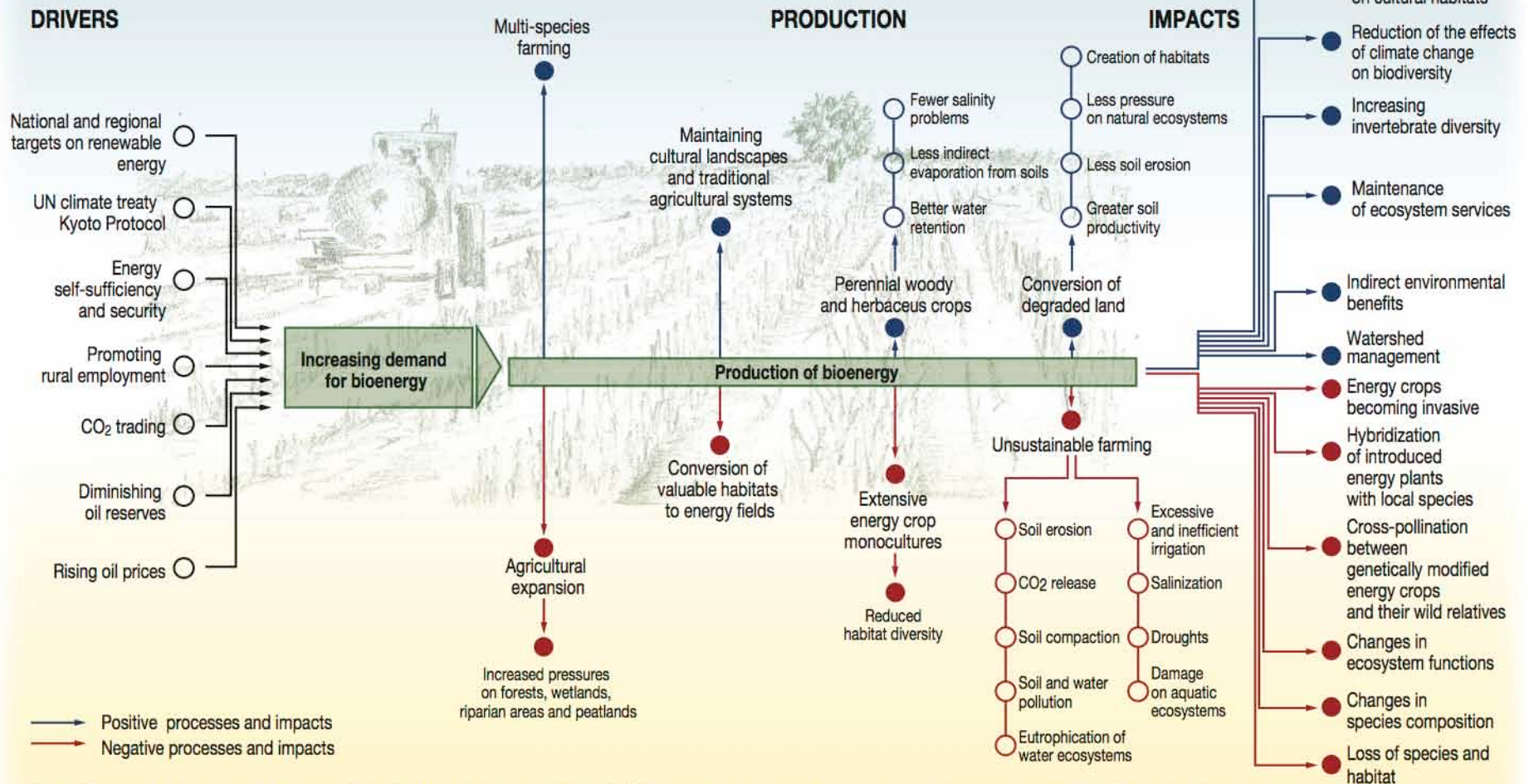
Figure 3.2.6 Forest carbon sequestration

The use of Genetically Engineered Crops (GECs) carries both potential benefits and risks. While it is recognised that they can help to introduce useful traits and increase productivity, there are also concerns about adverse ecological impacts. The balance between risks and benefits is likely to vary according to the different conditions of individual countries. It is advisable that comprehensive

biosafety risk assessments are conducted before governments make decisions on Genetically Engineered biofuel crops.

Beneficial effects for biodiversity are only expected when abandoned, formerly intensively used farmland or moderately degraded land is used and reconstituted; an agricultural-system approach must also be used.

Bioenergy from agriculture: factors related to biodiversity



Source: E. Furman et al., *Bioenergy-biodiversity interlinkages*, Finnish Environment Institute, 2009; UNEP and WCMC, *The impacts of biofuel production on biodiversity, a review of the current literature*, 2009; V. Dornburg et al., *Bioenergy revisited: Key factors in global potentials of bioenergy*, Energy and Environmental Science, 2010.

Figure 3.2.7 Bioenergy from agriculture: factors related to biodiversity

Water.

Water is a critical and potentially limiting factor for the development of biofuels. The agricultural sector already uses over 70 percent of available freshwater resources. By 2025 an estimated 1.8 billion people will live in areas with absolute water scarcity. Some of the same pressures on land availability also apply to water availability, such as population growth. Climate change may also change rainfall patterns, which could then affect local water supplies.

Water is a critical and potentially limiting factor for the development of biofuels...

Figure 3.3.1 compares the water necessary to produce, transport, and convert a given crop into a fuel in two different regions. This shows important variations, and points to the need for careful matching of energy crops and production and conversion systems with available water supplies. The global trade in biofuel crops has created a 'virtual water exchange' where some countries with low water resources 'export' their water in the form of biofuels.

It is important to consider not only the efficient use of water in the context of a single activity, but also the cumulative effects of several activities in one region on a watershed. Usually a distinction is made depending on the source of the water, for example whether production is entirely rainfed or irrigation is needed. An illustration of the water requirements of selected biofuel crops shows which biofuels demand the most water.

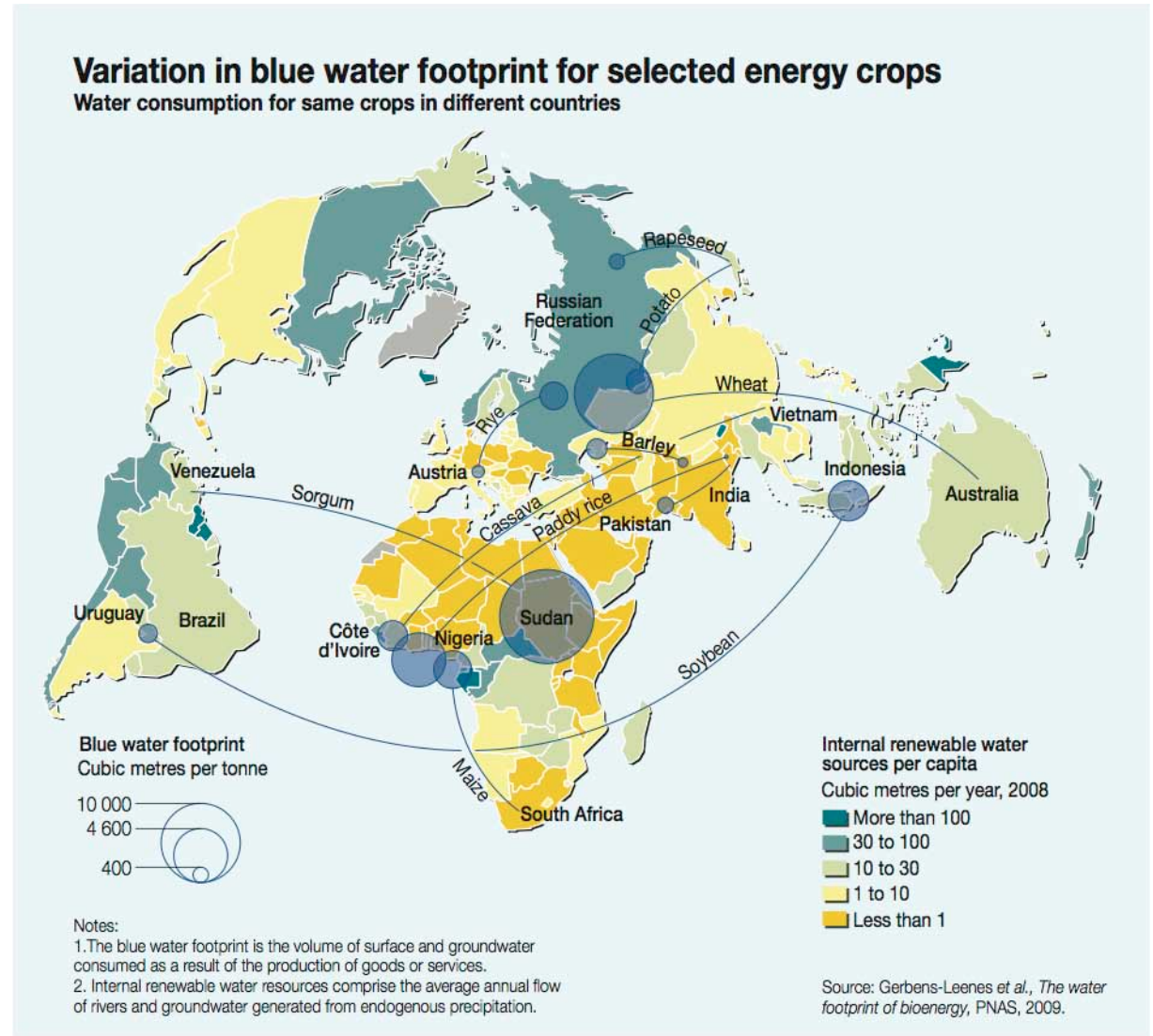


Figure 3.3.1 Variation in blue water footprint for selected energy crops

Box 3.3.1 Water footprint

The water footprint of an individual, community or business is defined as the total volume of freshwater used to produce and consume goods and services. It is an indicator of water use that looks at both direct and indirect water-use of a consumer or producer. Water use is measured in water volume consumed (evaporated) and/or polluted per unit of time.

The total water footprint comprises three different types of water – green water, blue water and grey water. Green water refers to water which has evaporated during crop

growth; Blue water is the amount of (evaporated) surface and ground water used for irrigation; and Grey water refers to water contaminated during the production process.

The international Standard for Water Footprinting specifies requirements and guidelines to assess and report the water footprint based on LCA. The standard aims for consistency with carbon footprinting and other LCA impact categories.

Source: UNEP (2009) Guidelines for Social Life Cycle Assessment of Products, UNEP (2010) <http://lcinitiative.unep.fr>

The water footprint is one of several concepts and tools developed to measure the impact of water flow and consumption in terms of quality or quantity. Applying various tools helps to gain a more comprehensive view of effects, both isolated aspects as well as interrelated effects of biofuel

production and agriculture. Water availability varies in space and time, so water appropriation should always be considered in its local context. This can be measured by studying the changes in isotopic composition of local water, or standard mean ocean water (SMOW).

Moreover, underlying data sources need to be interpreted in context. For example, rainfed jatropha is produced in Mali as a biofuel, which means that it receives less water than in many comparable contexts, but also with somewhat lower output of biofuel. India in contrast, has been irrigating jatropha to achieve commercially acceptable yields. The two contexts will produce different water footprint measurements. Sugarcane is a good example of how these figures might be confusing, because sugarcane is a water-intensive crop but, depending on local conditions, it can have a lower water footprint relative to fuel output.

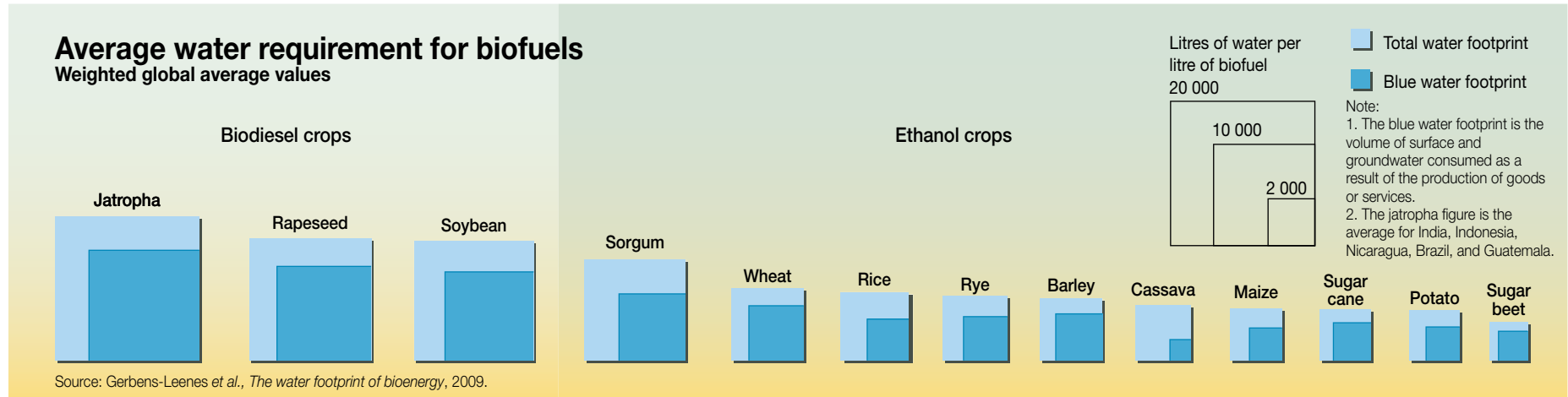


Figure 3.3.2 Average water requirement for biofuels

Nitrogen runoff

Increase according to crop scenario for 2016, baseline 2007

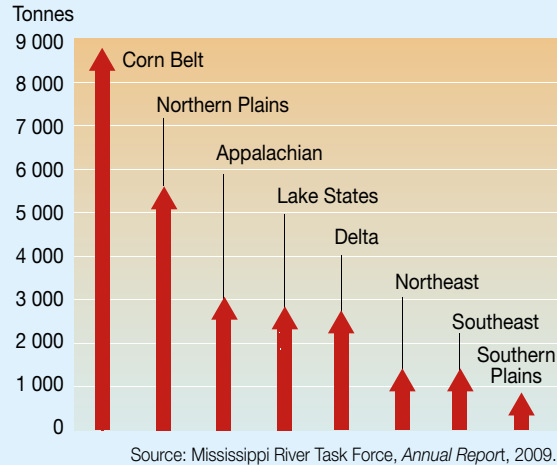


Figure 3.3.3 Nitrogen runoff

Water quality issues are also important. Fertiliser and pesticides used to cultivate feedstocks, as well as contaminated effluents discharged from conversion plants, can cause increasing levels of pollution to waterways. This may constrain the growth of biofuels production in developed and developing countries with already high agricultural production levels.

An example illustrates the level of nitrogen persistent in various regions of the United States and agrochemical use for different feedstocks.

Agrochemical use in US agriculture

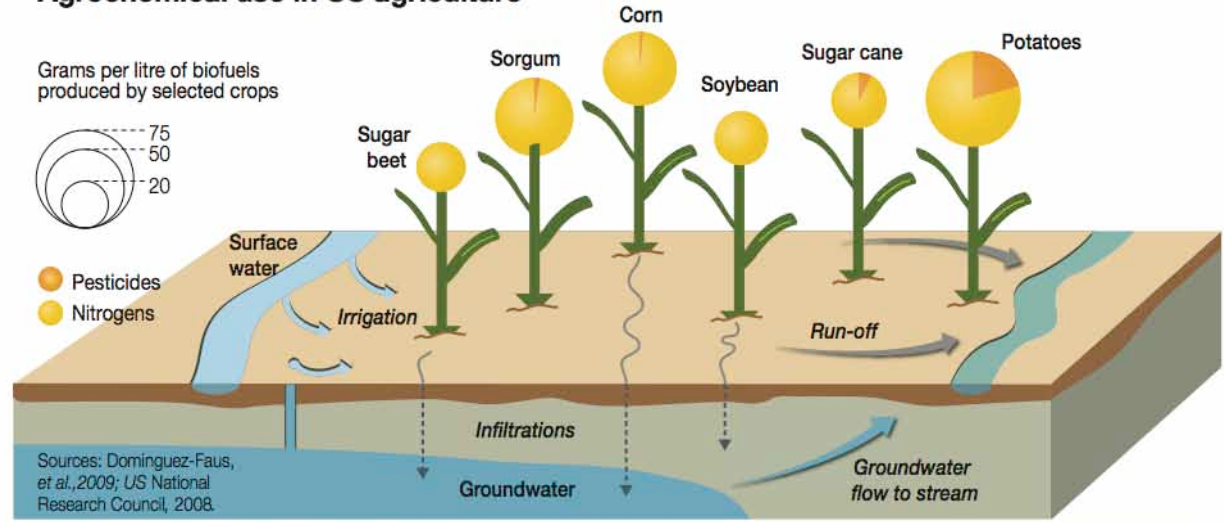


Figure 3.3.4 Agrochemical use in US agriculture

Similarly, agricultural runoff is pervasive in the Mississippi river basin, an area also known as the country's corn and ethanol belt. Although much of the runoff is linked to corn production for food, feed and fodder, further increases in biofuel crops might cause an overload in runoff into these water bodies to the point where they cannot recover. It is worth noting that a potential collapse of the watershed could occur as a result of the cumulative effects of environmental stress from agricultural production

alone, and not just from biofuels production. This example highlights the need to enact policies safeguarding overall water availability and quality over an entire watershed, promote water-efficient biomass production, and implement water-efficient management methods.

Agriculture in the Mississippi River Basin

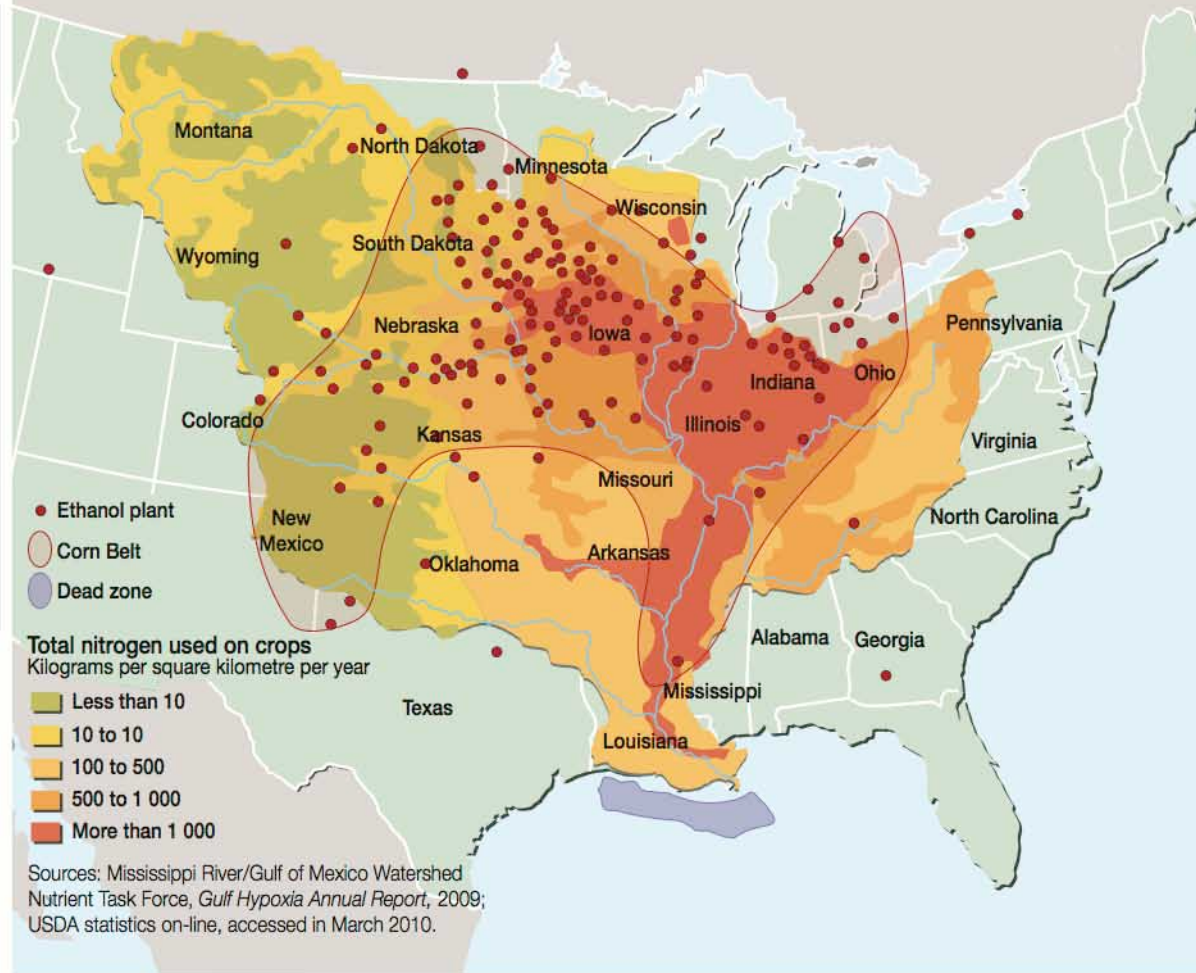


Figure 3.3.5 Agriculture in the Mississippi River Basin

Biofuels in China: crop production and water scarcity

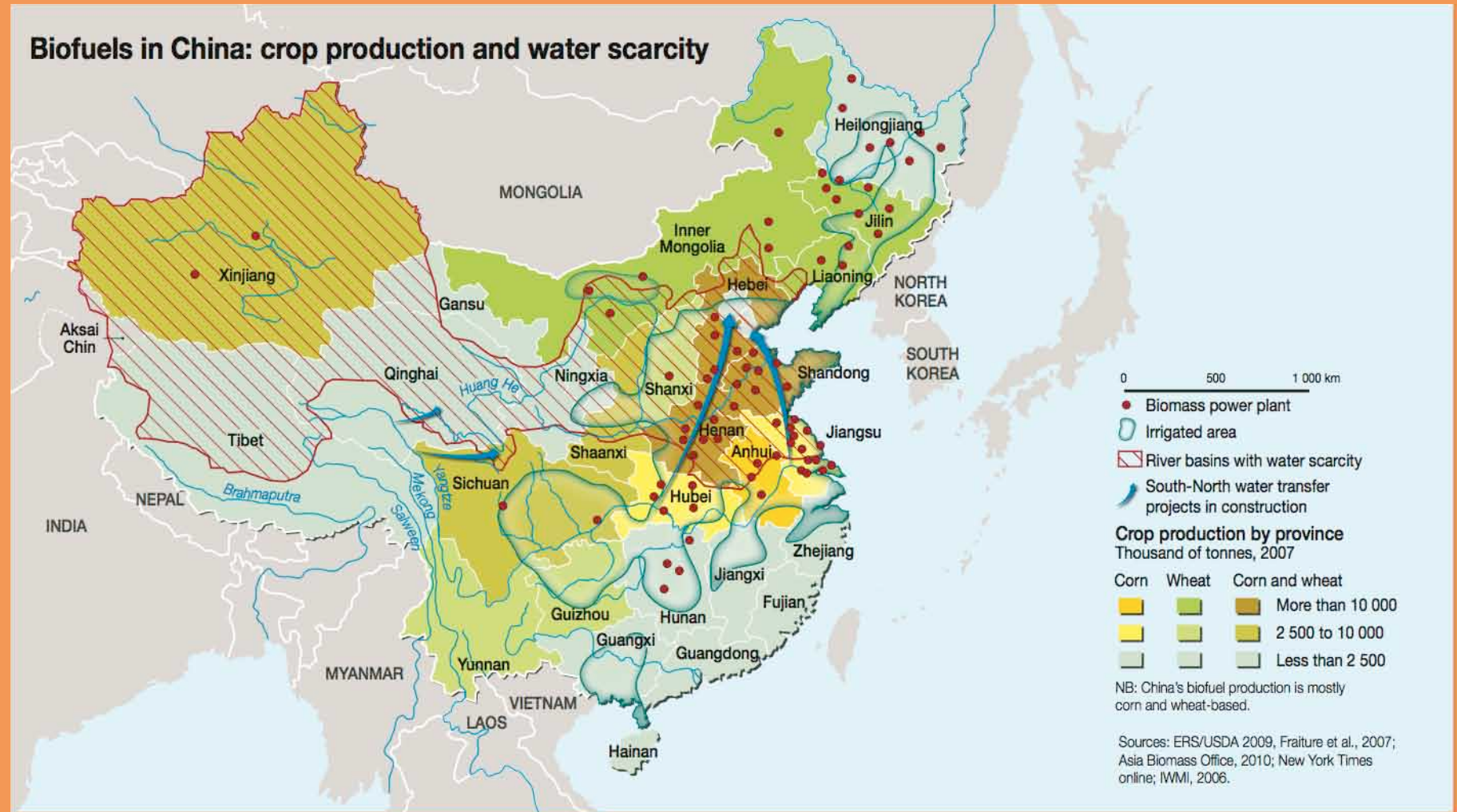


Figure 3.3.6 Biofuels in China: crop production and water scarcity

Box 3.3.2 Firm strategy for biofuels in China

In 2009 China produced 2 billion litres of biofuels, ranking the country third behind Brazil and the USA. The Chinese government has set ambitious targets seeing biofuels as not only contributing to the country's rapidly expanding energy needs, but also as a way of providing rural employment. With China having 20 percent of the world's population but only seven percent of its arable area, biofuels production is clearly constrained by land availability. However, a far more precious resource may be the most limiting factor yet: water.

Southwest China has seen large biofuels development partly sustained by access to large water reserves including two of the world's great rivers – the Yangtze and the Mekong. Despite access to a more plentiful supply of water from these rivers there are concerns about the impact of mass cultivation of biofuels on water resources and quality. In the north, with only 14 percent of China's water resources, the challenges related to biofuels production could be far more acute, according to the China Institute of Water Resources and Hydropower Research.

Water management is an increasingly difficult balancing act between electricity generation, food production, industrial use and direct human consumption. An example of a water management strategy in China is the recent South-to-North Water Diversion Project. Started in 2010, it is an example

of ambitious geo-engineering to rewire the water map of China. This project seeks to quench the thirst of stressed regions in the north facing, amongst other things, the possibility of expanded biofuels production that would inherently compete for the same water as is needed for growing other crops, including food.

Recognising these interactions, and in response to price increases for food crops around the world in 2007-8, the government has imposed a ban on further construction of biofuels plants using grain as feedstock. Chinese biofuels production – so far mostly based on corn and wheat – is now looking for other feedstocks, including those for advanced biofuels. Effects on overall food production and land use remain to be monitored.

The case of China illustrates the importance of national planning processes, such as creating comprehensive water-management strategies, and addressing the complexity of interactions at the outset. At the same time, biofuels policies should be flexible to allow scope for adjusting them and national strategies as science and research advance.

Source: Global Subsidies Initiative (2008). Biofuels – at what cost? Government support for ethanol and biodiesel production in China. U.S Department of Agriculture (2009). China Biofuels Annual. GAIN Report Number: CH9059 IEA (2010). Sustainable Production of Second Generation Biofuels www.iea.org/papers/2010/second_generation_biofuels.pdf ICRAF: The World Agroforestry Centre (2007). Biofuels in China: An analysis of the opportunities and challenges of *Jatropha curcas* in SW China.

Making it Happen.

Biofuels Vital Graphics demonstrates the potential of biofuels to deliver a range of energy and development objectives as a cornerstone of the global green economy. But it will only be possible to secure their place in the green economy if a number of safeguards are implemented at both national-policy and local-project levels, to avoid creating any additional environmental or social problems.

Biofuels are not created equal, and the sustainability of the bioenergy sector depends on complex and interrelated choices which are often region and even site-specific. Awareness of potential problems and innovative solutions creating multiple co-benefits are key to informed decision making.

Effective policies are critical to developing a sustainable biofuels sector, providing for sound investments and the most suitable technology. Technological development must strive for optimal resource use and allocation, whilst minimising waste and inefficiencies, ultimately leading to economic efficiency. Policies need to be science-based and cross-sectoral, reflecting a long-term, life-cycle approach along the entire supply chain.

Box 4.1 Fuelling Uganda's green economy

Recently Uganda has outlined its national strategy for bioenergy to contribute to increasing the renewable-energy mix from 4 to 16 percent by 2017. Alongside the energy challenge, the country faces a number of other difficult tasks including loss of ecosystems and systemic low rural employment. Ugandan officials have pointed out that in addition to serving as a new source of renewable energy, growing crops for bioenergy can help tackle unemployment and bring more cash to often impoverished rural communities. At the same time, biofuel production could reduce the country's dependence on imported fossil fuels, and help tackle serious energy shortages. These benefits, of course, can only be harnessed if safeguards are implemented, for example to protect forests as the country has already lost 65 percent of its forests over the past 40 years.

Several biofuel crops have been identified, including sugarcane, maize, oil palm and jatropha. A suitability assessment of these crops illustrates that the potential output from certain biofuel feedstocks is high. Several projects are underway to help the country meet their target.

To reduce the potential loss of biodiversity and related ecosystem services which this new development may entail, measures are needed to

Pressures on Ugandan forests Energy demand

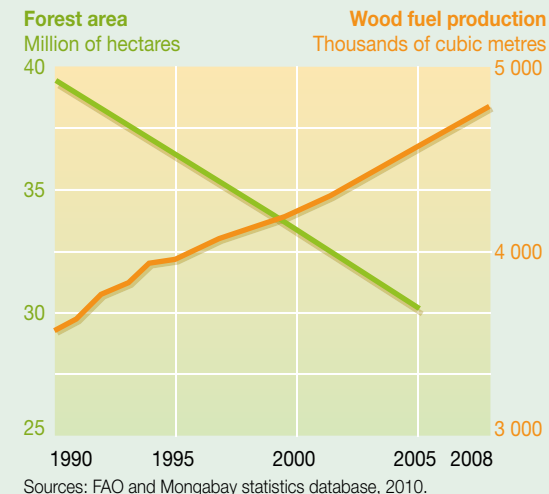
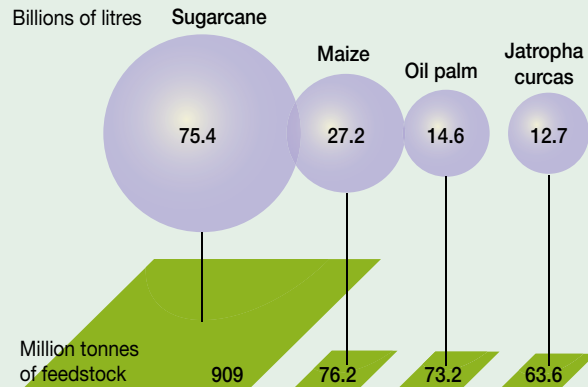


Figure 4.1 Pressures on Ugandan forests

designate areas where the crops can be grown safely. Mapping of areas of high biodiversity and High Value Conservation Areas (HVCAs) should go hand-in-hand with surveys of crop/land suitability before contracts are awarded for bioenergy projects..

Potential biofuels output in Uganda



Source: Narl-Kwanda/NEMA, *The potential of biofuel in Uganda*, 2010.

Figure 4.2 Potential biofuel output Uganda

Such agro-environmental mapping is key to ensuring that bioenergy delivers on its green economy potential.

Africa Reporting Project (2010) Biofuels take root in Uganda as experts warn of severe hunger <http://africareportingproject.org/2010/03/08/biofuels-take-root-in-uganda-as-experts-warn-of-severe-hunger/> New Scientist (2007) Biofuel plantations fuel strife in Uganda www.newscientist.com/article/dn11671-biofuel-plantations-fuel-strife-in-uganda.html The Guardian (2009) Oil find sparks new hope for Uganda's people www.guardian.co.uk/world/2009/aug/25/uganda-oil-find-energy-companies

Suitability by crop type in Uganda

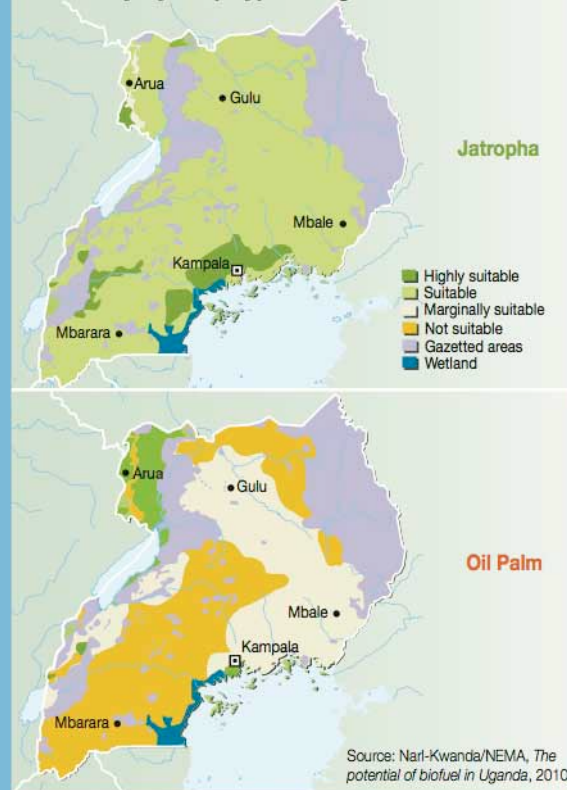


Figure 4.3 Suitability by crop type in Uganda

The research community, business leaders and government representatives have all pointed to a number of measures, which can reduce potential pressures and impacts while maximising benefits. These include steps to increase resource productivity and efficiency, to foster sustainable land approaches, implement strategies to reduce carbon emission, and target energy access to achieve development goals. In considering the economic efficiency of the overall energy mix, qualifiers such as less water input, improved local access, and the effects and impacts compared with alternative energy sources should be examined; and when appropriate, safeguards should be applied. Choosing the appropriate means to provide bioenergy, and energy as a whole, is often about trade-offs.

Increase resource productivity and efficiency

Improving the efficiency of feedstock production, conversion and use helps increase resource productivity and thereby reduce pressure on land, water and other resources. Increasing yields and optimising agricultural production can augment output on existing cropland without encroaching on natural land. This is particularly relevant in developing countries where there is significant potential to increase crop and land productivity. There is also scope for harnessing investments in biofuels development to modernise the agricultural sector and help build capacity, which can promote overall agriculture production for food, materials and fuel.

Different biofuels pathways have different efficiencies in the growth of feedstocks, conversion processes and end-uses. This chain of efficiency pertaining to input and output needs to be considered in national planning processes to identify the most suitable biofuel feedstocks for a given country, region and local context. For example, the energy potential of landfill material is released through combustion, whereas bioethanol, (both from crops such as corn and wheat, and from cellulose such as grass and wood) is obtained through conversion.

The development of biorefineries can greatly support efforts to increase resource efficiency. Biorefineries integrate biomass conversion processes and equipment to produce fuel, power, and chemicals from biomass. By producing multiple

products, a biorefinery can take advantage of the differences in biomass components and intermediate products, thus maximising the value of a biomass feedstock (Figure 4.5).

Increasing the productivity of biorefineries is a vital part of the bioenergy supply chain. Interconnected closed biorefinery systems can capture waste products and integrate them back into the biorefinery process. Such measures to increase efficiency contribute to reducing GHG emissions from decomposing biorefinery waste, and to creating other value-added products.

Decreasing the overall use of water in biorefineries is also essential. Incorporating grey water systems, which re-circulate used water can reduce the water footprint of some feedstocks.

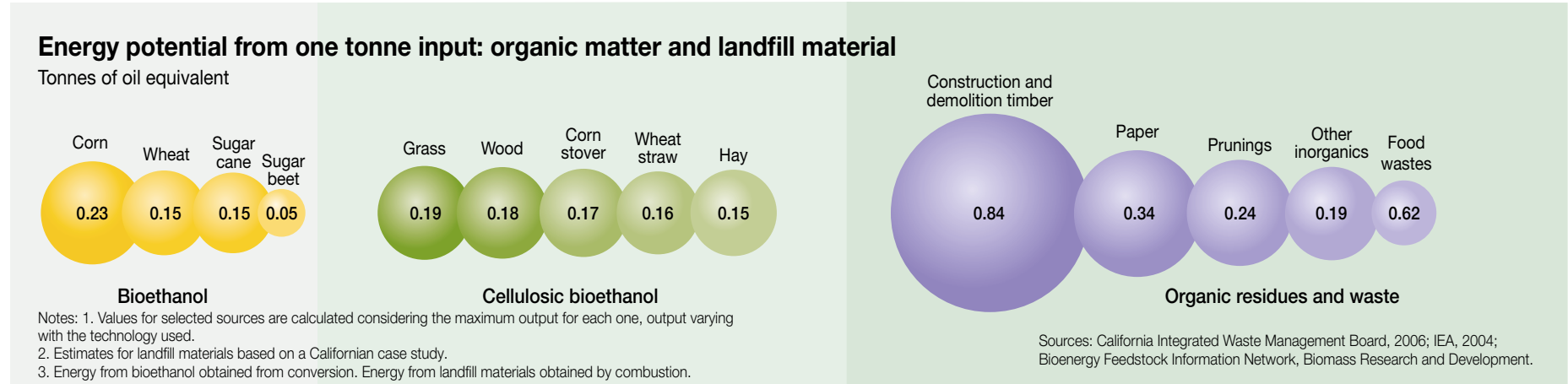


Figure 4.4 Energy potential from one tonne input: organic matter and landfill material

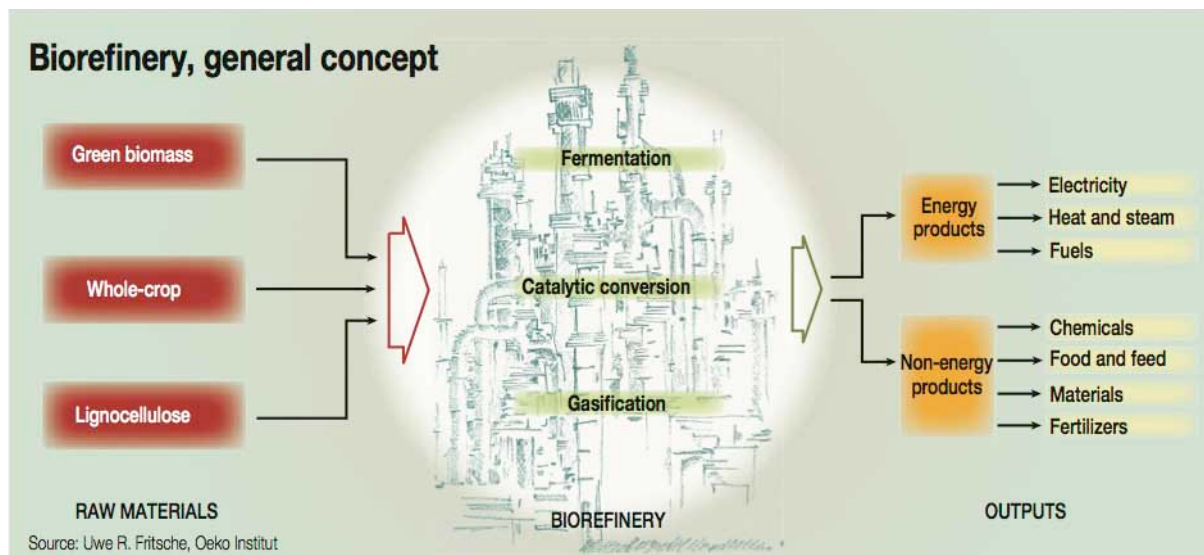


Figure 4.5 Biorefinery, general concept

More efficient use of biomass is also needed, including the optimal use of waste and residues. Specifically, energy recovery from municipal organic waste and residues from agriculture and forestry hold significant, yet largely untapped energy potential. With little or no environmental impact, recovery of these materials yields many co-benefits, including a cut in carbon emissions otherwise released through traditional disposal or combustion.

However, not everything that looks like waste is unused. Assessments of potential competing waste

uses, such as soil fertiliser, as well as longer-term availability of the waste stream should be made prior to developing a biofuel plant.

Bioenergy offers many ways to combine uses, for example by using biomass first to produce material and then recovering the energy content of the resulting waste (cascading use). The forestry sector has been maximising the use of wood products by creating value with its residue waste stream – providing biomaterials for both fibre and fuel. Often these residues can be pelletised and burnt in cogeneration plants to supply heat and power.

Box 4.2 Bioenergy-efficiency

The use of sisal, a plant native to East Africa, is a good example of how the bioenergy-efficiency concept can be put into practice. Traditionally sisal is used to make fibre and twine, with 2-4 percent of the total plant being used and the rest discarded to decompose. But sisal waste is now being used as a value-added product to generate biogas in various areas of East Africa. Using the whole sisal plant now doubles carbon emission savings by eliminating decomposition of sisal waste.

Sources: UNIDO Available at: www.unido.org/index.php?id=6464

Finally, consideration should be given to the most efficient end-use of biomass. For example, stationary use of biomass to generate heat and/or electricity is typically more energy-efficient than converting biomass to a liquid fuel. Of course, economic efficiency may lead to a different conclusion, and future trends with fossil fuels becoming more difficult to extract may change the equation of environmental benefits.

Box 4.3 Oil palm production in Indonesia

The challenge of preventing encroachment on sensitive areas has become apparent with the expansion of oil palm production in Asia. For instance Indonesian oil palm developments, to date largely for food production, have led to high levels of deforestation. However, growing oil palms in areas such as the Imperata Grasslands, rather than on wooded and peat land, is part of a more sustainable biofuels development strategy. This grassland covers an estimated 8 million hectares; a sizeable area considering the total area for oil-palm plantations is about 10 million hectares. Using this land could ensure more sustainable oil-palm biodiesel production by limiting indirect land-use impacts and preserve biodiverse forests.

Source: Dehne, B., Meyer S. and van de Staa, J. (2010): Responsible Cultivation Areas. Identification and certification of feedstock production with a low risk of indirect effects. Ecofys Available at: www.ecofys.com/en/publications/17/

Foster sustainable land use

Land-use planning is one strategy to manage competition for land and, at the same time, reduce environmental and social impacts. Assessment of land suitability and availability can identify both high-risk areas where land conversion should be avoided, and areas where bioenergy production is appropriate. Such assessments need to consider a range of variables including:

- Temperatures and water balance, topography and soil types;
- Climate-change projections and adaptation needs;

Potential biofuels production on abandoned agricultural land

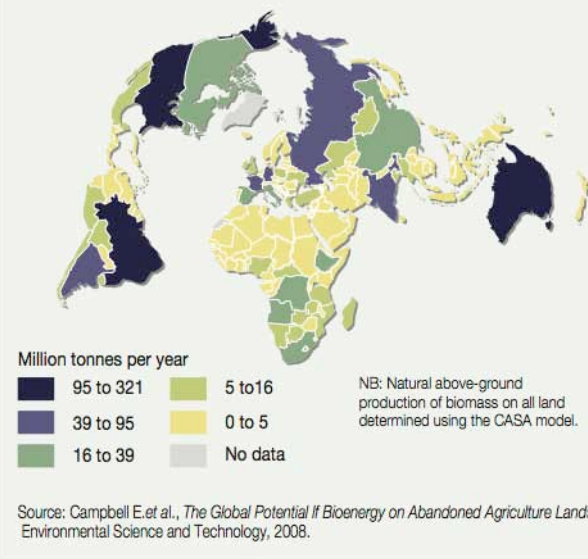


Figure 4.6 Potential biofuels production on abandoned agriculture land

- Screening for environmentally sensitive areas;
- Impact on ecosystem services;
- Current land cover and use, including land used for housing, agriculture and cultural/medicinal areas; and
- Conflict zones, archaeological sites, land tenure, and infrastructure issues.

These assessments produce the best results when using a combined top-down (GIS /spatial data) and bottom-up approach (ground-truthing, stakeholder involvement).

Restoring formerly degraded land and using under-used and/or abandoned land can boost output without increasing pressure to convert land. Careful assessment is needed as such land may harbour high levels of biodiversity, cultural values, or have been deliberately set aside.

Maximise greenhouse gas reductions

Many countries have already shown that bioenergy can be part of a comprehensive national emissions reduction strategy, and integrated as part of national planning in processes such as National Appropriate Mitigation Strategies (NAMAs). Such planning processes help identify the most efficient combination of approaches to reduce GHG emissions.

As discussed above, the various biofuels pathways all entail different GHG impacts, with land use being a critical aspect. For example, growing oil palms on degraded land results in a better life-cycle carbon balance than converting peatland into oil-palm monocultures.

Improving efficiency all the way through the biofuels life cycle can reduce total emissions. For example, sustainable agricultural practices rather than current practices, can cut emissions, with even bigger gains when crop and energy systems are integrated. In Brazil integrating food-energy systems and recovering sugarcane bagasse for energy has maximised the GHG benefits of bioenergy.

Small-scale bioenergy applications: impacts on livelihood

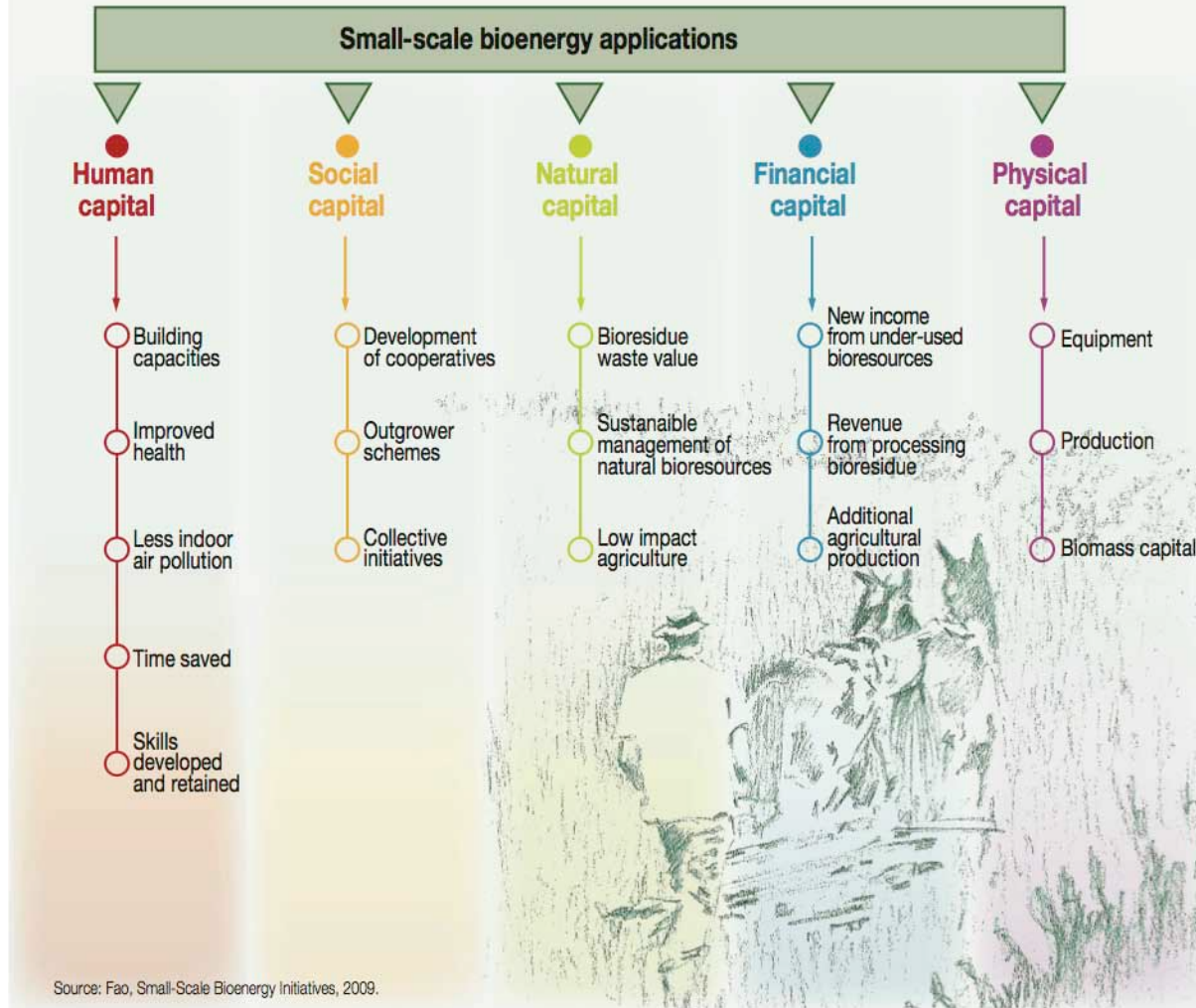


Figure 4.7 Small-scale bioenergy applications: impacts on livelihood

Contribute to energy access and encourage social and economic development

Energy access is a primer for any type economic development. Nowhere is energy access a greater challenge than in areas and regions where the population lives in poverty. As illustrated in this publication, bioenergy can deliver considerable positive social impacts to these communities.

Small-scale bioenergy applications, such as generators fuelled by biofuels, can power many technologies which increase productivity and output, including water pumps to irrigate crops. Alternative fuel stoves are another technology which can be integrated easily to decrease the use of wood fuels for cooking, and replace low-quality energy sources with modern biofuels such as ethanol.

Box 4.4 Cambodia harnesses bioenergy in small applications with a big impact

In Bot Trand village, Cambodia, most families are involved in subsistence farming, owning less than one hectare of land. With per capita incomes averaging about US\$2 a day many families, if faced with a bad agricultural year, have a hard time affording basic necessities including food. Recognising the pressure that the high cost of diesel imposes on these families, a jatropha project was started to generate employment and offset the high cost of fuel. Jatropha has been grown for many years in Cambodia.

Over the past few years a small energy revolution has taken place in the village of Bot Trang in northwest Cambodia. Bot Trang is not on Cambodia's national

grid: in the old days Mr. Tham Bun Hak, a local farmer, would supply 80 households in the village with electricity from his diesel fired generator – but now it's all run on jatropha. With the assistance of local NGOs and public partnerships, Mr. Tham developed a jatropha project that has made jatropha oil two-third less expensive than diesel. Now more affordable electricity can be delivered to the village and because of that, every family has been able to save money.

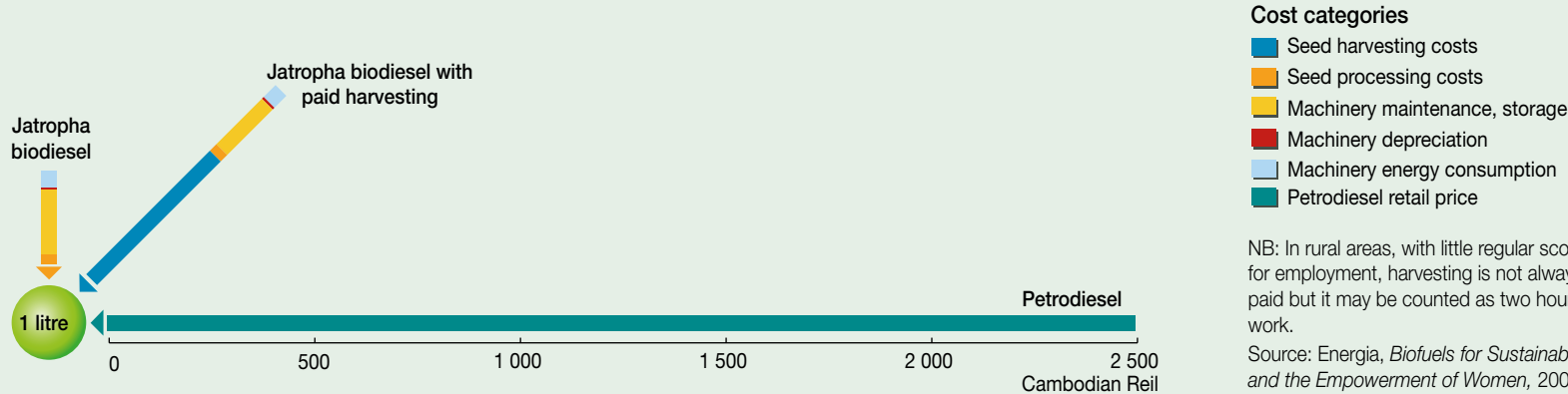
Besides electricity generation, Jatropha has brought other benefits. Villagers earn extra income by growing jatropha and that extra income can help fuel further entrepreneurship and business. For example, families such as the Tham family now have additional capital

to make their business more efficient. The capital has given them the opportunity to replace old sewing machines with more efficient electric ones, and they are able to increase productivity.

Other villages in Cambodia are now following Bot Trang's example and using jatropha fuelled power. This case study illustrates that bioenergy can foster economic development and help to grow even small, local Green Economies.

Sources: Energia (2009) Biofuels for Sustainable Development and the Empowerment of Women. Case Studies from Africa and Asia, University of Amsterdam (2006) Size Does Matter: The possibilities of cultivating jatropha curcas for biofuel in Cambodia

Energy costs in Bot Trang village, Cambodia



Reflections on the way forward.

Biofuels Vital Graphics offers a snapshot of the complexity and shortcomings of biofuels, while also addressing their potential for contributing to a green economy.

There is no doubt that biofuels can play a part in fuelling the green economy. Biofuels, as one form of bioenergy, have been and will be part of the energy mix, and can contribute to achieving renewable energy targets meant to replace fossil fuels.

There is a difference between the technical and the sustainable potential of biofuels. Further implementation of agricultural good practices and technological development will gradually increase their sustainable potential.

Safeguards are needed to address challenges that may stand in the way of healthy national, regional and global market developments for biofuels. With the right safeguards and policy frameworks in place, biofuels can offer a focused, pragmatic approach as one option for green energy. This comprises sound planning at the outset, and matching of drivers, crops, conversion routes and end-use.

It is expected that most of the potential for growth in biomass production is in developing countries. This may provide many countries with an opportunity to develop a new industrial sector, to cater for both, the internal and the international markets.

Achim Steiner, Executive Director of UNEP, has stated 'With 2.5 billion people living on less than US\$ 2-a-day and with more than 2 billion people being added to the global population by 2050, it is clear that we must continue to develop and grow our economies. But this development cannot come at the expense of the very life support systems on land, in the oceans or in the atmosphere that sustain our economies, and thus, the lives of each and everyone of us.'

The actual energy mix and potential for bioenergy development are contingent on country conditions and needs, but do also need to be seen in a broader context of global challenges. Albeit not the focus of Biofuels Vital Graphics, this points to a need for a shift in consumption patterns through a keen awareness of the impact of modern lifestyles.

Acronyms.

FAO	Food and Agriculture Organisation of the United Nations
GHG	greenhouse gas
GM	genetically modified
GISP	Global Invasive Species Programme
HVCA	High Value Conservation Areas
ICRAF	World Agroforestry Centre
IEA	International Energy Agency
IEO	International Employers Organisation
IFAD	International Fund for Agricultural Development
IFES	integrated food-energy systems
IIED	International Institute for Environment and Development
ILO	International Labour Organisation
IPC	International Food & Agriculture Trade Policy Council
ITUC	International Trade Union Confederation
LCA	life cycle assessment
LUC	land-use change
iLUC	indirect land- use change

NAMA	National Appropriate Mitigation Strategies
NREL	National Renewable Energy Laboratory
REIL	Renewable Energy and International Law
SCOPE	Scientific Committee on Problems of the Environment
SMOW	standard mean ocean water
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
WCMC	World Conservation Monitoring Centre
UNIDO	United Nations Industrial Development Organisation
USDA	United States Department of Agriculture
UNCTAD	United Nations Conference on Trade and Development
WWF	World Wildlife Fund

Chemical abbreviations

CO ₂	carbon dioxide
FAME	fatty acid methyl ester

References .

Africa Reporting Project: Biofuels take root in Uganda as experts warn of severe hunger <http://africareportingproject.org/2010/03/08/biofuels-take-root-in-uganda-as-experts-warn-of-severe-hunger/>, accessed 26 July 2010

Asia Biomass Office: Future Supply Targets of Bioethanol and Biodiesel in Southeast Asia, www.asiabiomass.jp/english/topics/1001_05.html, accessed 26 July 2010

Bates, J., Howes, P., Dent, C., Brown, A., Rapson, D. (2008). Review of Indirect Effects of Biofuels. Evaluation of the drivers of land use change and Review of future demand and supply of biofuels to 2020 and their impact on GHG-emissions Report by AEA Energy & Environment to The Renewable Fuels Agency

Blanco-Canqui, H. (2010). Energy Crops and Their Implications on Soil and Environment. *Agronomy Journal* (102), March-April 2010: 403-419 American Society of Agronomy

Biofuels Platforms:
www.biofuels-platform.ch/en/infos/production.php?id=biodiesel,
www.biofuels-platform.ch/en/infos/bioethanol.php,
accessed 8 June 2010
<http://advancedbiofuelsusa.info/truly-sustainable-renewable-future>,
accessed 8 June 2010
www.biofuelus.com/biofuel/what-is-advanced-biofuel.php,
accessed 8 June 2010

Bringezu, S. et al. (2009). Global Implications of Biomass and Biofuel Use in Germany: Recent trends and future scenarios for domestic and foreign agricultural land use and resulting GHG emissions. *Journal of Cleaner Production* (17):57-68 International Trade in Biofuels www.sciencedirect.com/science?_ob=ArticleURL&_udi=B6VFX-4W8KHJJ-1&_user=10&_coverDate=11%2F30%2F2009&_rdoc=1&_fmt=high&_orig=search&_sort=d&_docanchor=&view=c&_acct=C000050221&_version=1&_urlVersion=0&_userid=10&md5=4e0a80052e585228db831ccd8f0c8e32

Budny, D., Sotero, P. (2007). The Global Dynamics of Biofuels: Potential Supply and Demand for Ethanol and Biodiesel in the Coming Decade. Woodrow Wilson International Center for Scholars. Brazil Institute Special Report April 2007 (3)

Bureau International des Poids et Mesures (2005). Comité International des Poids et Mesures. 94th meeting (October 2005) www.bipm.org/utis/fr/pdf/CIPM2005-FR.pdf, accessed 8 July 2010

California Energy Commission (2006). Biomass in Solid Waste in California: Utilization and Policy Alternatives DRAFT. PIER Collaborative report. White paper

California Integrated Waste Management Board's (CIWMB) Strategic Plan: Potential for Creating Bioenergy and Biofuels from Landfill-Bound Residuals and Landfill Gas, May 2007.

Campbell, A. and Doswald, N. (2009) The impacts of biofuel production on biodiversity: A review of the current literature. UNEP-WCMC, Cambridge, UK

Campbell, J., Lobell, D., Genova, R. and Field, C. (2008). The Global Potential of Bioenergy on Abandoned Agriculture Lands. *Environmental Science & Technology* 42 (15):5791-5794 American Chemical Society Publications

Clarens, A.F., E.P. Resurrection, M.A. White and L.M. Colosi (2010). Environmental Life Cycle Comparison of Algae to Other Bioenergy Feedstocks. *Environmental Science and Technology* 44 (5):1813-1819

Cohen, M. and Evans, J. (2008): The Water Resource Implications of Large-Scale Bioethanol Production, School of Forest Resources and Conservation, University of Florida

Cotula, L., Dyer N. and Vermeulen, S. (2008). Fuelling exclusion? The biofuels boom and poor people's access to land. IIED, London.

Dijkman, T (2009). Effective Land Use for Renewable Energy Sources. University of Groningen. IVEM, Centre for Energy and Environmental Studies <http://irs.ub.rug.nl/dbi/4a894d1b76d3d>, accessed 29 July 2010

Dominguez-Faus, R., Powers, S., Burken, J. and Alvarez, P. (2009). The Water Footprint of Biofuels: A Drink or Drive Issue? American Chemical Society Publications: *Environmental Science & Technology*. 43: 3005-3010

Ekvall, T.: Presentation at InLCA-LCM 2002, Methods Development www.lcacenter.org/lca-lcm/session-methods.html, accessed 30 July 2010
www.springerlink.com/content/q174j0831697m738/, accessed 30 July 2010

FAO's website. www.fao.org/ag/ca/, accessed 4 August 2010

FAO (2008). The state of food and Agriculture 2008. Biofuels: prospects, risks and opportunities, 2008. www.fao.org/docrep/011/i0100e/i0100e00.htm, accessed 4 August 2010

FAO (2006). Climate change, biofuels and land [ftp://ftp.fao.org/nr/HLCinfo/Land-Infosheet-En.pdf](http://ftp.fao.org/nr/HLCinfo/Land-Infosheet-En.pdf), accessed 4 August 2010

Fargione J., Hill, J., Tilman, D., Polasky, S. and Hawthorne, P. (2008). Land Clearing and the Biofuel Carbon Debt. *Science* 319 (1235):1235-1238

Fischer, G., Hiznyik, E., Sylvia Prieler Mahendra Shah, S and Harrij van Velthuisen, H. (2009). Biofuels and food security – Implications of an accelerated biofuels production OFID study prepared by IASA, 2009 www.ofid.org/publications/PDF/biofuels_book.pdf, accessed 4 August 2010

de Fraiture, C., Giordano, M and Liao, Y. (2008). Biofuels and implications for agricultural water use: blue impacts of green energy *Water Policy* 10 Supplement 1, 2008 67-81.

Gerbens-Leenes, W., Hoekstra, A., van der Meer, T. (2009). The water footprint of bioenergy. *Proceedings of the National Academy of Sciences of the United States*, www.pnas.org/cgi/doi/10.1073/pnas.0812619106, accessed 30 July 2010

GISP newsletter issue 9 December 2007
www.gisp.org/publications/newsletter/GISPnewsletter9.pdf,
accessed 26 July 2010

Global Subsidies Initiative of the International Institute for Sustainable Development (2008). Biofuels – at what cost? Government support for ethanol and biodiesel production in China ISBN: 978-1-894784-24-5

Groom, M., Gray, E. and Townsend, P. (2008). Biofuels and Biodiversity: Principles for Creating Better Policies for Biofuel Production. *Conservation Biology* 22 (3):602-609 Society for Conservation Biology

Gross, M. (2008). Algal biofuel hopes. *Current Biology* 18 (2): R46-R47, www.cell.com/current-biology/retrieve/pii/S0960982207024311, accessed 30 July 2010

The Guardian (2009) Oil find sparks new hope for Uganda's people, August 2009
www.guardian.co.uk/world/2009/aug/25/uganda-oil-find-energy-companies,
accessed 30 July 2010

Hoekstra, A. Y. (2009). A Comprehensive Introduction to Water Footprints – Water Footprint Network presentation

Hoekstra, A.Y., Chapagain, A.K., Aldaya, M.M. and Mekonnen, M.M. (2009). Water footprint manual: State of the art 2009, Water Footprint Network
www.waterfootprint.org/?page=files/Publications, accessed 26 July 2010

Hooijer, A, Silvius M., Wösten H. and Page S. (2006): PEAT-CO₂, Assessment of CO₂ emissions from drained peatlands in SE Asia. Delft Hydraulics report Q3943

Hossain, A.B.M.S., A. Salleh, A. Nasrulhaq Boyce, P. Chowdhury and M. Naquiddin. (2008). Biodiesel fuel production from algae as renewable energy. American Journal of Biochemistry and Biotechnology 4 (3):250-254

Howarth, R.W. and Bringezu, S. (2009). Biofuels: Environmental Consequences & Implications of Changing Land Use. Proceedings of the Scientific Committee on Problems of the Environment (SCOPE) International Biofuels Project Rapid Assessment, 22-25 September 2008. Gummertsbach, Germany

ICRAF (2007). Biofuels in China: An analysis of the opportunities and challenges of *Jatropha curcas* in SW China
www.worldagroforestrycentre.org/sea/Publications/Files/workingpaper/WP0088-07.PDF, accessed 30 July 2010

IEA (2010). Sustainable Production of Second Generation Biofuels
www.iea.org/papers/2010/second_generation_biofuels.pdf,
accessed 4 August 2010

IEA (2004). Biofuels for Transport – An International Perspective
www.iea.org/textbase/nppdf/free/2004/biofuels2004.pdf,
accessed 4 August 2010

IFAD's website: www.ifad.org/rainfedag/conservation/index.htm,
accessed 8 July 2011

IFAD (2011). www.ifad.org/rainfedag/conservation/index.htm,
accessed 8 July 2011

IPC and REIL (2006). WTO Disciplines and Biofuels: Opportunities and Constraints in the Creation of a Global Marketplace. IPC Discussion Paper
www.agritrade.org/Publications/DiscussionPapers/WTO_Disciplines_Biofuels.pdf,
accessed 4 July 2010

Johnson, M. B. and Wen, Z. (2010). Development of an attached microalgal growth system for biofuel production. Applied Microbiology Biotechnology 85:525–534

Keeney, D. and Nanning C. / Institute for Agriculture and Trade Policy (2008). Biofuel & Global Biodiversity.

Knight, P. (2010): Sugar and Ethanol in Brazil in 2010. World Ethanol & Biofuels Report. ISSN 1478-5765

de Laeter J. R., Böhlke J. K., De Bièvre P., Hidaka H., Preiser H. S., Rosman K. J. R. and Taylor P. D. P. (2000). Atomic Weights of the Elements: Review 2000 (IUPAC Technical Report). Pure and Applied Chemistry 75 (6):683-799

Le Monde Diplomatique (4) (2009). Brazil: who gets the cake?

Le Roy, D. and Klein, K. (2007). The Development and Sustainability of the Biofuel Industry in Canada. National Agricultural Biotechnology Council (NABC) Report. Agriculture Biofuels: Technology, Sustainability and Profitability. 19:177-185

Malcolm, S. and Aillery, M./USDA (2009). Growing Crops for Biofuels Has Spillover Effects. Amber Waves 7 (1): 10-15
www.ers.usda.gov/AmberWaves/March09/Features/Biofuels.htm,
accessed 26 July 2010

Menichetti, E. and Otto, M. (2009). Energy Balance & Greenhouse Gas Emissions of Biofuels from a Life Cycle Perspective, 81-109. In Howarth, R.W. and Bringezu, S. (2009). Biofuels: Environmental Consequences & Implications of Changing Land Use. Proceedings of the Scientific Committee on Problems of the Environment (SCOPE) International Biofuels Project Rapid Assessment, 22-25 September 2008. Gummertsbach, Germany

Millennium Development Goals Indicators UN official website:
<http://mdgs.un.org/unsd/mdg/default.aspx>, accessed 26 July 2010

Mississippi River/Gulf of Mexico Watershed Nutrient Task Force: What is hypoxia and what causes it? www.epa.gov/msbasin/hypoxia101.htm,
accessed 26 July 2010

Mississippi River/Gulf of Mexico Watershed Nutrient Task Force (2008). Gulf Hypoxia Action Plan 2008 for Reducing, Mitigating, and Controlling Hypoxia in the Northern Gulf of Mexico and Improving Water Quality in the Mississippi River Basin
<http://water.epa.gov/type/watersheds/named/msbasin/actionplan.cfm>,
accessed 26 July 2010

Mother Nature Network. www.mnn.com/earth-matters, accessed 30 July 2010

Nationmaster.com: People Statistics
www.nationmaster.com/graph/peo_pop-people-population&date=1960,
accessed 26 July 2010.

New Scientist (2007): Biofuel plantations fuel strife in Uganda
www.newscientist.com/article/dn11671-biofuel-plantations-fuel-strife-in-uganda.html, accessed 30 July 2010

NREL: What is a Biorefinery? www.nrel.gov/biomass/biorefinery.html,
accessed 25 July 2010

NREL/Bain, R. (2007). World Biofuels Assessment – Worldwide Biomass Potential: Technology Characterizations, Milestone Report
www.nrel.gov/docs/fy08osti/42467.pdf, accessed 8 July 2010

Owen, A. (2006). Renewable energy: Externality costs as market barrier. Energy Policy 34:632–642

Pienkos, P.T. and Al Darzins. (2009). The promise and challenges of microalgal-derived biofuels. Special Issue: Cutting Edge Biotechnologies in Bioenergy and Bioproducts 3 (4):431-440

Renewable Energy Policy Network for the 21st Century (REN 21). Renewables 2011 Global Status Report. www.ren21.net/, accessed 24 August 2011

Reuters: Brazil Must Save Forests in Ethanol Push: Clinton
www.reuters.com/article/idUSTRE55123020090602, accessed 8 June 2010

Reuters: FACTBOX-Britain's power generation sources
<http://uk.reuters.com/article/idUKLK25045820090721> accessed 26 July 2010

Sano, D. and Romero, J. (2010). Biofuels in China: strategies and some implications. Presentation, Institute for Global Environmental Strategies

Sawyer, D. (2008). Climate change, biofuels and eco-social impacts in the Brazilian Amazon and Cerrado. Philosophical Transactions of the Royal Society B-Biological Sciences 363:1747-1752

Shay, E.G. (1993). Diesel fuel from vegetable oils: status and opportunities. Biomass Bioenergy 4:227-242

Sumatra Orangutan Conservation Programme
www.sumatranorangutan.org/content-n49-sE.html, accessed on 26 July 2010

The Times: Britain cuts down forests to keep 'green' power stations burning
www.timesonline.co.uk/tol/news/environment/article6918024.ece,
accessed 26 July 2010.

UNDP: How can we track MDG process? www.undp.org/mdg/progress.shtml, accessed 26 July 2010.

UN-Energy (2007) Sustainable bioenergy: a framework for decision makers. Available at: www.fao.org/docrep/010/a1094e/a1094e00.htm, accessed 26 July 2010

UNEP: One Year On – Many Countries Factoring Environmental Investments into Economic Stimulus Packages www.unep.org/Documents/Multilingual/Default.asp?DocumentID=596&ArticleID=6325, accessed 26 July 2010

UNEP (2011) Green Economy Report. Renewable energy. Investing in energy and resource efficiency www.unep.org/greeneconomy/Portals/88/documents/ger/GER_6_RenewableEnergy.pdf, accessed 24 May 2011

UNEP (2009) Bioenergy Issue Paper No. 2, Water and Bioenergy www.unep.fr/energy/bioenergy/issues/issuepaperseries.htm, accessed 8 July 2010

UNEP (2009). Towards Sustainable Production and Use of Resources: Assessing Biofuels www.unep.org/PDF/Assessing_Biofuels.pdf, accessed 29 July 2010

UNEP (2007). Global Environmental Outlook 4 www.unep.org/geo/geo4.asp, accessed 26 July 2010

UNEP/GRID-Arendal, FAO, UNFF (2008). Vital Forest Graphics <http://grida.no/publications/vg/forest/>, accessed 26 July 2010

UNEP/ILO/IOE/ITUC (2008). Green Jobs: Towards Decent Work in a Sustainable, Low-Carbon World. ISBN: 978-92-807-2940-5

UNCTAD (2006). The emerging Biofuels Market: Regulatory, Trade and Development Implications www.unctad.org/en/docs/ditcted20064_en.pdf, accessed 8 July 2010

USA's Energy Independence and Security Act of 2007 http://energy.senate.gov/public/_files/getdoc1.pdf, accessed 26 July 2011

U.S Department of Agriculture (2009). China Biofuels Annual. GAIN Report Number: CH9059

U.S Department of Energy (2008). World Biofuels Production Potential – Understanding the Challenges to Meeting the U.S. Renewable Fuel Standard. Washington

U.S Environmental Protection Agency, Office of Transportation and Air Quality (2010). Renewable Fuel Standard Program (RFS2) Regulatory Impact Analysis Assessment and Standards Division www.epa.gov/otaq/fuels/renewablefuels/regulations.htm, accessed 26 July 2010

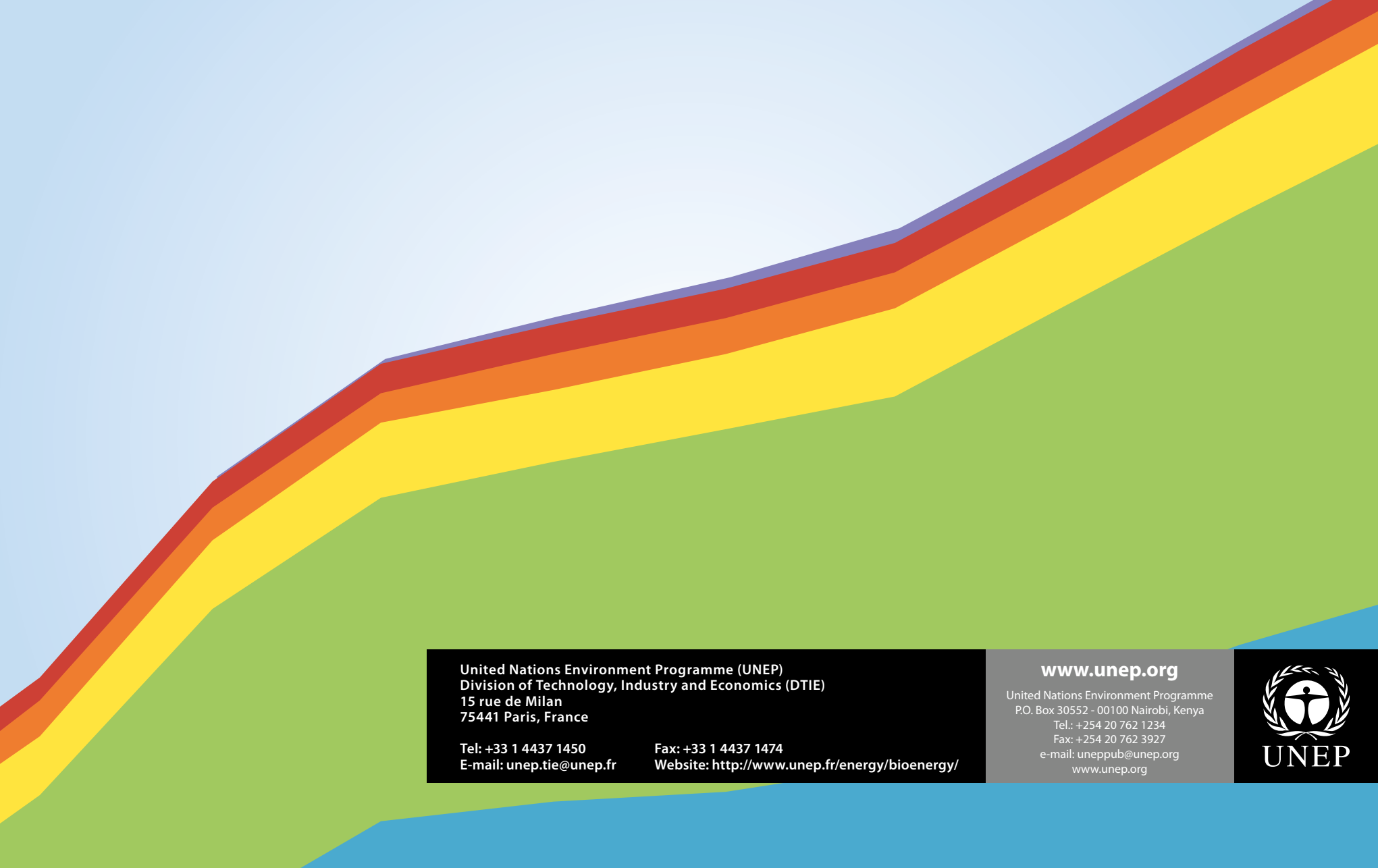
Varghese, S. (2007). Biofuels and Global Water Challenges. Institute for Agriculture and Trade Policy (IATP) Report, Minneapolis

Vyas, A.P, Verma, L. and Subrahmanyam, N. (2010). A review on FAME production processes. Fuel 89(1):1-9

Wang, M., Wu, M. and Huo, H. (2007). Life-cycle energy and greenhouse gas emission impacts of different corn ethanol plant types IOP Publishing: Environmental research letters <http://stacks.iop.org/ERL/2/024001>, accessed 26 July 2010

Wijffels, R., Barbosa, M., Eppink, M.(2010). Microalgae for the production of bulk chemicals and biofuels. Biofuels, Bioproducts and Biorefining 4(3): 287-295

World Bank (2008). Biofuels: The Promise and the Risks, World Development Report: Agriculture for Development WWF: Orang-utans under threat www.wwf.org.uk/how_you_can_help/orangutans_under_threat_b.cfm, accessed 26 July 2010



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