AG0397

RNRA Team

PROGRAMME OF ADVISORY SUPPORT SERVICES FOR RURAL LIVELIHOODS

DEPARTMENT FOR INTERNATIONAL DEVELOPMENT

FINAL TECHNICAL OUTPUT

Report Title:

Biofuels, Agriculture and Poverty Reduction

PASS Project Code

AG0397

Project Title:

Biofuels, Agriculture and Poverty Reduction

Project Leader

Rachel Slater

Institution

Overseas Development Institute

Adviser requesting project

Daniel Bradley

Report Date

March 2007

Declaration:

This document is an output from a project funded by the UK Department for International Development (DfID) for the benefit of developing countries. The views expressed are not necessarily those of DfID.

Biofuels, Agriculture and Poverty Reduction

March 2007

Leo Peskett, Rachel Slater, Chris Stevens (ODI)
Annie Dufey (IIED)

Table of Contents

Introduction

Some fairly lofty claims have been made about the role of biofuels in development and poverty reduction. Knight (2007) argues that energy crops are beginning a green revolution in Brazil. Chaturvedi (2006) suggests that a bioproduct-based agro-revolution can offer a new development paradigm for the developing world. Read (2004) argues biofuels can provide a solution to the twin problems of poverty and climate change. Similarly, de Keyser and Hongo (2005) claim that in fuel importing developing countries biofuels can: enable rural job creation and food security; reduce oil imports and generate savings on foreign exchange; demonstrate tropical comparative advantage in production; improve domestic and regional energy production capacity; and enable economic diversification.

Elsewhere there is scepticism. Pimental and Patzek (2005) question the net energy benefits of biofuels production and show how energy outputs from corn, switchgrass and wood biomass ethanol were less than the fossil energy inputs required to produce them. Mayat (2007) suggests that biofuels will be a 'pandora's box' and questions whether large-scale biofuel production can be environmentally, socially and economically sustainable and efficient.

Despite these concerns, alarm over greenhouse gas (GHG) emissions, rising oil prices and new biofuels targets in the North mean that development stakeholders are interested in the role of the agricultural sector in biofuels production.

This paper examines the scope for biofuels production and trade to contribute to agricultural growth and poverty reduction in developing countries. We do not consider the broader questions about biofuels and energy policy here. We pose the following questions:

- What is the potential contribution of biofuels to agricultural sector development and economic opportunities for poor people in rural areas?
- What might future scenarios of enhanced biofuel production mean for small farmers, agricultural labourers, the non-farm economy and for food security?
- What will the impact be on rural growth and poverty reduction? and
- Will biofuels offer a lifeline to rural economies, or largely bypass poor people?

Biofuels are defined here as *organic primary and/or secondary fuels derived from biomass which can be used for the generation of thermal energy by combustion or by using other technology. They comprise both purpose-grown energy crops, as well as multipurpose plantations and by-products (residues and wastes)* (FAO 2000). In this paper we will focus on two main types of liquid biofuels produced from purpose-grown, land-based energy crops:

- **Bioethanol** is an alcohol derived from sugar or starch crops (e.g. sugar beet, sugar cane or corn) by fermentation. Cellulosic materials (e.g. wood, grasses and some waste crop residues) can also be converted into bioethanol, via a more complicated process but currently only at laboratory scale. Ethanol can be used in either neat form in specially designed combustion engines, or blended with petroleum fuel.
- **Biodiesel** is derived from vegetable oils (e.g. rapeseed oil, jatropha, soy or palm oil) by reaction of the oil with methanol. Waste residues (e.g. waste cooking fat) can also be converted into biodiesel. Biodiesel can either burnt directly in diesel engines or blended with diesel derived from fossil fuels.

The paper is structured as follows: Section 1 reviews global trends in biofuels production, consumption and trade and highlights market opportunities for poor developing countries. Section 2 draws on these global trends to consider international trade in biofuels and the implications for regulation. Section 3 considers the extent to which biofuels production, processing and trade can and are likely to contribute to growth and poverty reduction. Section 4 analyses what biofuels expansion might mean for food security. Section 5 considers the environmental implications of biofuels whilst in Section 6 we focus on research priorities before concluding with a set of policy and research recommendations. Some parts of the work include very detailed and comprehensive information and these have been included in an annex. For example, annex 1 reviews the main sources of information drawn on under each part of the report.

1. Trends and Policies

The first large-scale schemes for biofuel production began in the early 1970s (e.g. in Brazil and the US), but only recently have biofuels been given notable worldwide consideration as a fossil fuel alternative. Early experiences were mainly motivated by the need to reduce import bills and increase energy security, though latterly rural support appeared as an important driving force. Current high oil prices mean that the same goals for biofuels are still at the top of the policy agendas, but in additional new driving forces have emerged including biofuels' potential to contribute to mitigating climate change, providing new end-markets and export opportunities for agricultural commodities and even providing alternatives to the illegal production of some crops (e.g. coca).

1.1 Current production

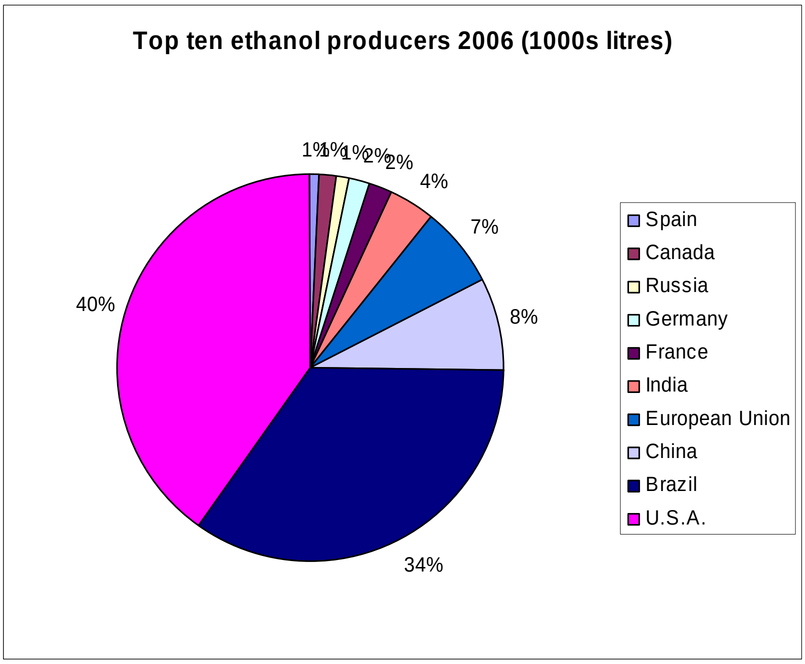


Figure 1: World top 10 bioethanol producers. Source: Based on F.O. Licht 2006, cited in RFA 2007

Production of biofuels for domestic use and export is dominated by a few countries. Bioethanol, production of which began in the 1970s, is still produced in much larger volumes than biodiesel for which production started in the 1990s. The US and Brazil are the largest producers of bioethanol by a large margin (Fig. 1). The EU produces almost 95% of the world's biodiesel. Global production has increased gradually over time.

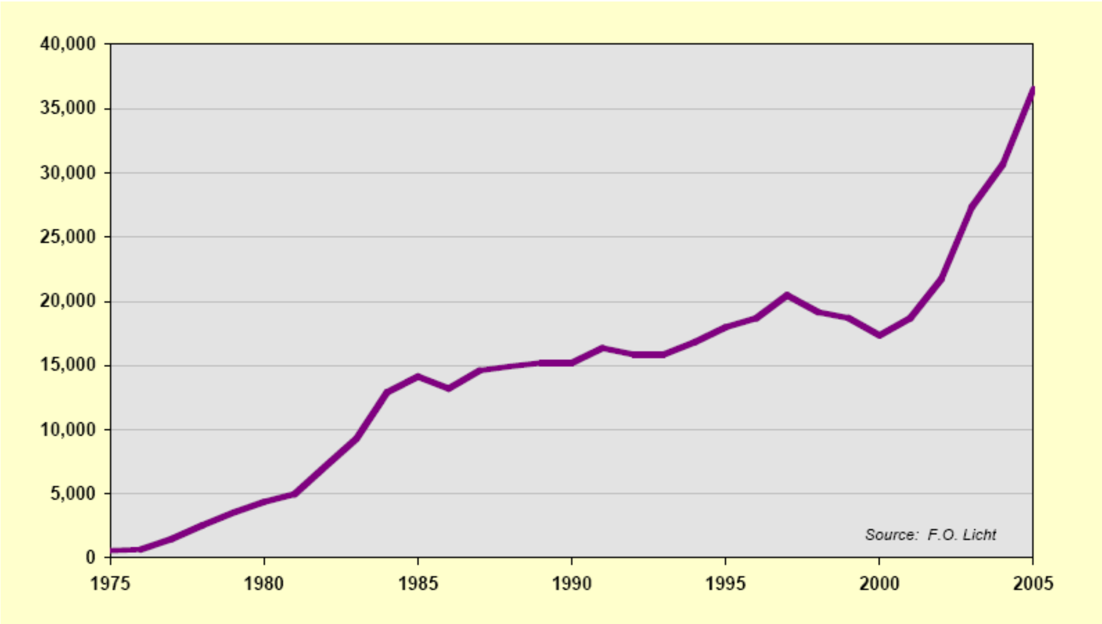


Figure 2: World fuel ethanol production, millions of litres, 1975-2005. Source F.O. Licht 2005, cited in Worldwatch Institute 2006

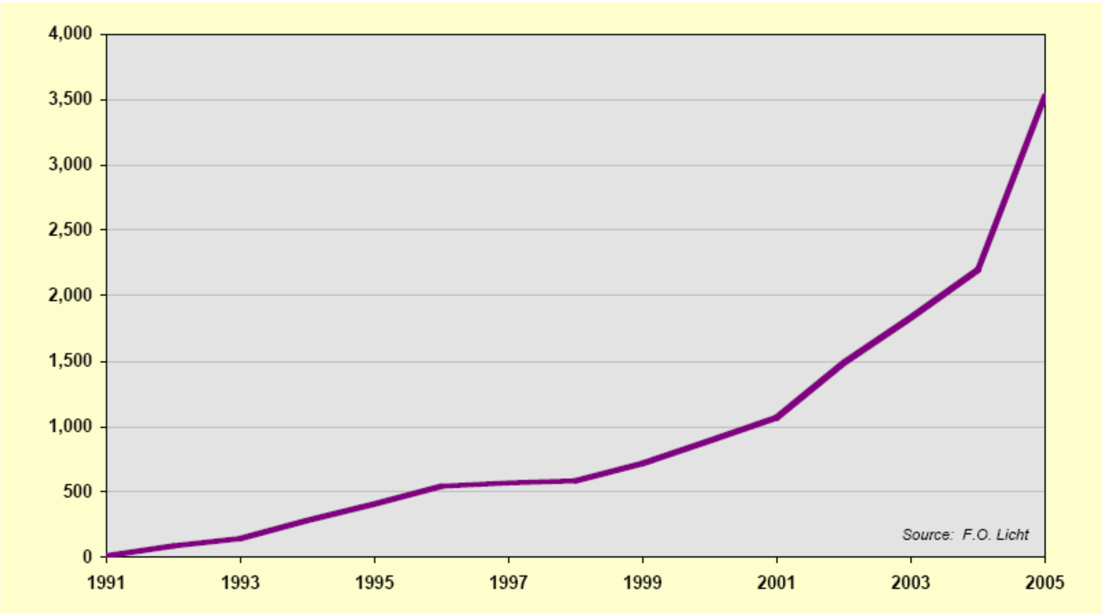


Figure 3: Global biodiesel production, millions of litres, 1991-2005. Source F.O. Licht 2005, cited in Worldwatch Institute 2006

1.2 Projections in production

Various countries have set biofuels targets in transport fuels which give some indication of likely national and global demand over the next decade. Some targets are shown in Annex 5. The largest increases in production volumes are expected in Brazil, the US, the EU, China, India, Indonesia and Malaysia.[1] The few analyses that have been done based on current production and future policies and targets indicate that annual global production of bioethanol will increase to 120 billion litres by 2020 (IEA 2004). Annual biodiesel production will increase to 12 billion litres by 2020. Recent changes in EU and US policy mean these figures are likely to increase.

1.3 Projections in trade

Comparing current production trends and targets with different countries' ability to produce biofuels domestically gives an indication of how biofuels trade is likely to develop over the next two decades. In general existing trade relationships in biofuels are likely to be strengthened with volumes increasing over time.

Brazil is currently the largest exporter of bioethanol and has a large capacity to expand its industry to meet domestic and export targets. By 2011 around 20% of Brazilian bioethanol production (5.2 million litres) will be exported. The largest importers are India and the US, mainly sourcing bioethanol from Brazil (Dufey 2006). Recent initiatives between the US and Brazil suggest this trade relationship will be strengthened. Caribbean countries are increasing export production, particularly to the US. Significant imports will also emerge in countries that cannot produce large enough volumes of biofuels domestically to meet targets. Japan and South Korea in particular are likely to source bioethanol and biodiesel from Brazil and from Asian countries such as the Philippines, Malaysia and Indonesia.

Biodiesel trade is currently much more limited than trade in bioethanol. The most significant increases in trade will most likely be exports from Malaysia and Indonesia to the EU, which has a biofuels target of a 10% blend of biofuels in transport fuel by 2020. Brazil is also developing large-scale biodiesel production from soya oil and plans to export. The US began palm oil-based biodiesel imports from Ecuador in 2005 and these imports are expected to increase rapidly.

1.4 Opportunities for small developing countries

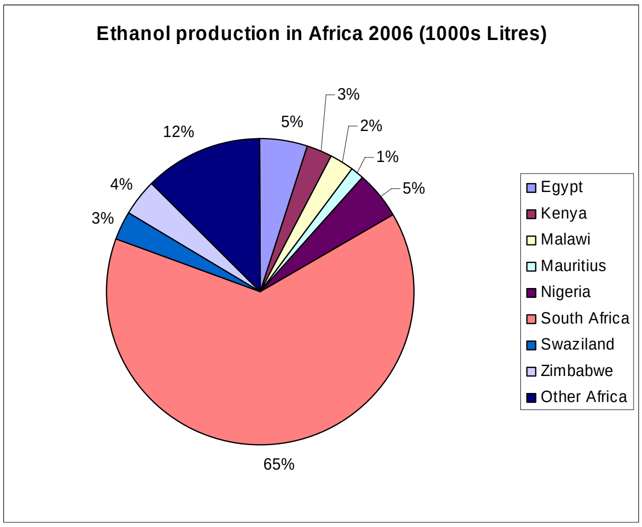


Figure 4: Comparison of ethanol production in different African countries. Source: Based on F.O. Licht 2006, cited in RFA 2007

[1] Differences in the ways that production targets are quoted (e.g. units of measurement, target dates, aggregation of different fuel types etc.) make it difficult to draw comparisons between countries without more detailed analysis.

Making predictions about future production based on current targets can be misleading, as other countries are yet to set targets and develop biofuels industries. Smaller developing countries with large areas of land suitable for growing biofuels crops *could* substantially increase production if their industries are competitive with world fuel markets.

Whilst current production of biofuels in small developing countries is limited, it is not new. Malawi initiated a bioethanol programme in 1982 and now has a production capacity of 18 million litres per year. The government of Malawi, as with many other governments in Africa including Mali and Burkina Faso, is encouraging the planting of jatropha for biodiesel production. South Africa is currently the largest producer of bioethanol from sugarcane (Fig. 4).

In Latin America, countries like Ecuador, Colombia and Peru have already introduced targets for biofuels and embarked upon production (Albán and Cárdenas, forthcoming, UPME 2006, UNCTAD 2006). Colombia, Ecuador and Peru are also looking for export opportunities. Caribbean countries, where the EU sugar regime reform could reduce regional sugar revenues by 40%, are seizing opportunities derived from biofuels trade to diversify the sugar industry. South East Asian countries such as the Philippines and Thailand have introduced aggressive policies for biofuels and begun production.

2. International Trade and Markets

Despite rapid increases in the production and use of biofuels, the sector is still in its infancy, particularly in relation to international trade, and so much remains uncertain. Predicting future trade patterns is hard given the rapid development of technology (which may alter current economies of scale) and of environmental pricing (that may alter the commercial feasibility of moving biofuels around the globe). Given the uncertainty this section explains how a biofuel production and consumption system based on a relatively liberal international trade regime would tend to produce different effects from one in which international trade is artificially restricted by government policy.[2]

Agricultural and Energy Price Effects

Combining technological improvements in using biological materials for fuel with increasing oil prices opens the prospect of a very substantial potential increase in global demand for arable crops. It is not the only source of potential demand increase but it is a substantial one.[3]

If extra demand is not matched by an equivalent increase in supply world prices will rise. Broadly speaking, the effect of this would be to increase the incomes of producers

2 'Relatively liberal' means that the principle determinant of whether biofuels are traded internationally are: the relative costs of production in different parts of the world (taking account of any pricing of particular 'environmental costs'; the costs of transferring biofuels from one country that has a net surplus to another with a deficit (again, taking account of any environmental taxes on transport); and the structure of the market in relation to the extent to which proximity to the market is important for commercial success. 'Artificial restriction' describes government policies designed to alter the pattern of trade from what would be determined by the commercial factors described above, normally with the intention of supporting output levels by domestic producers at higher levels than would otherwise be the case.

3 Rising incomes in countries (like China and India) with largely cereal-based diets at present could result in a substantial increase in arable demand if their consumers shift to a more meat-based diet. And there are also potential shocks to the supply side, such as water shortage, that would have the same ultimate market effect.

(and countries that are in net surplus) and reduce those of consumers (and countries that are net importers).

- As between countries, therefore, there would tend to be a shift in favour of, for example, Argentina and Brazil and against much of Sub-Saharan Africa where food insecurity will increase.
- Within countries there would tend to be a shift in favour of agricultural producers (largely in rural areas) and against consumers (including those in urban areas but also those living in rural areas without the ability to participate in agriculture as farmers or labourers) – even in countries that are net importers.

There would be parallel shifts in the cost of energy. These would be less visible: oil prices will not necessarily fall, they are more likely simply to rise more slowly than they would otherwise have done. Nonetheless, this will tend to benefit countries that are net energy importers and disfavour those that are net exporters and do not also participate in the biofuel trade.

The gains for the net importers are not dependent upon their actually exporting biofuels or even producing them for import substitution. If world oil prices are less than they otherwise would have been, all net importers will pay less than otherwise (with the amount actually paid determined by bargaining strength, which is unlikely to change because of biofuels). The 'gains' for countries that can use domestic biofuel production to substitute for imported energy or produce a surplus for export is that they gain on both fronts: on increased prices for agriculture and lower prices for energy. But, as noted above, not all socio-economic groups within such countries will gain from higher agricultural prices. So there will always be distributional effects.

What would happen under liberal trade?

If there are no artificial restrictions on trade the international distribution of production will be determined very broadly (because in practice markets are never perfect and there are always a range of commercial considerations to favour one source of supply rather than other) by the relative cost of production (including transport to market). If there exist taxes intended to minimise use of resources that contribute most to climate change then the global pattern of production will also tend to see it concentrated in the areas where the contribution to climate change of producing biofuels is minimised.
One effect will be that the supply of biofuels increases most in the countries with the lowest constraints on raising their total level of arable production. Few if any countries are likely to have limitless production (especially in the short to medium term) but the trade-offs between using factors of production either for biofuels or for food/feed will be smaller in some countries than in others. The cost of producing biofuels in the countries where the trade-offs are small will tend to be lower than in countries where they are high.

Whilst it is impossible to forecast whether or not total demand for arable resources to supply biofuels will be matched by an increase in supply, the likelihood and scale of any shortfall will tend to be lower if the biofuels can be produced anywhere in the world, notably in countries that are relatively abundantly resourced in arable inputs, than if they cannot. Hence, any increase in world food prices will tend to be smaller in such a case than otherwise, but the parallel reduction in energy prices will be exactly the same.

The effects of trade restrictions

If biofuel production is encouraged in countries where it would not otherwise occur it will reduce the likelihood that global supply will increase as rapidly as demand for arable output. The characteristics of most OECD agricultural support regimes will exacerbate this tendency.

An increase in biofuel production in the EU or USA resulting in a decline in food/feed production could lead to a rise in world food/feed prices provoking, in turn, an increase in supply in countries with agricultural potential. But there are several steps in the chain of causality and plenty of reasons to suppose that any such supply-response will be muted compared to what would happen if countries like Brazil were permitted to supply directly biofuel demand in the major industrialised countries. Food/feed prices may have to rise further than they otherwise would in order to provoke any given supply response from Brazil or Argentina if the stimulus comes indirectly via reduced OECD exports of food or feed products.

A trade-off between biofuel and food/feed output is particularly likely because most OECD governments are concerned to cap agricultural support: increased biofuel demand offers a lifeline enabling farm incomes (and output) to be maintained at desired levels more easily. But it is improbable that biofuel demand will result in a reversal of policy towards an increase in European/US production across-the-board. Since an increase in biofuel production in the EU (especially) or other OECD states is particularly likely to result substitution for food/feed production rather than an increase in supply, it is likely to maximise any resulting increase in global food/feed prices and, hence, the shock for developing country producers and consumers.

Types of restriction to trade[4]

National

Countries (especially those in the OECD but also including developing countries with both the will and the resources to do so) tend to distort their agricultural markets in many, complex ways that restrict the level of trade, with direct subsidies for the use of domestically produced biofuels being just one, not necessarily the most important, source. Trade restrictive policies can be split into direct and indirect, and general or specific.

- *Direct, general restrictions*. The EU, EEA, USA, India, China, Brazil and others impose direct controls on imports of agricultural goods (and processed goods of agricultural origin) to raise domestic prices and ensure local farmers earn (and produce) more than would otherwise be the case. Import tariff regimes can be very complex and are often laced with preferences for some suppliers (altering the pattern of trade but normally keeping imports lower and more expensive than they would be under a liberal regime); the EU, for example, offers duty-free access to ethanol from almost 30 states plus the ACP and LDCs – but not to Brazil which must pay the high MFN tariff.
- *Direct, specific restrictions*. Import controls applied to crops that could be used for biofuels (or to products like ethanol) will tend to make domestic production of these items more attractive than they otherwise would be and reduce the share of output supplied by imports. However, farmers take their production decisions in relation to the full range of outputs that they are able to produce (given technical, market and regulatory constraints). So it is the relative price raising effects of protection on biofuels and ingredients on the one hand, and on all other arable products on the other that will determine whether or not domestic production of biofuels is enhanced or reduced.

As with other goods, technical standards may also discriminate against imports. Biofuels can be subject to both technical barriers to trade (TBT) on the processed

[4] A more exhaustive list of restrictions to trade is given in annex 4.

product and to sanitary and phytosanitary standards (SPS) on the raw materials. Restriction can occur either intentionally or accidentally, not least if they vary between markets in ways that make it more difficult for producers to reap economies of scale. It has been argued that the existence of diverging technical regulations in different countries, for instance, may constitute the most serious restrictions on biofuels trade (Dufey 2006).

- Indirect, general restrictions on trade are introduced by the subsidies that governments in most OECD states pay to their farming communities. As with trade protection, the impact on biofuel production is determined by the relative scale of subsidy to different types of output.
- Indirect, specific restrictions in the form of subsidies for domestically produced biofuels is a common practice, probably in every producing country.[5] Policies include support for feedstock production and biofuel processing. The USA, for instance, provides a US$ 0.51/gallon tax credit for bioethanol in the US and US$ 1 per gallon of biodiesel from virgin oils or fats (Dufey 2006). In overall it is estimated that US subsidies to bioethanol and biodiesel to be between US$ 5.5 billion and US$ 7.3 billion a year (Koplow 2006). The UK subsidizes the production of biofuels by about US$ 36 cents per litre (IPC-REIL 2006).

International

International regulatory regimes, such as WTO rules, can impinge on national policies in ways that could affect biofuel trade. Generally speaking, there is nothing that would limit a country's ability to liberalise its biofuel imports. Countries are free to sub-divide the internationally agreed customs product codes into sub-categories and, for example, to impose lower tariffs on inputs into bio-fuel production than on the same goods used for other purposes.

Problems might arise if a country wishes to increase its tariff on biofuels to exceed the limits to which it has committed in the WTO, or to subsidise domestic use of biofuels in ways that affect trade (either by hindering imports or increasing exports). Whilst subsidies that do not affect trade are not restricted in the WTO there may be a fine – and controversial – judgement on whether or not a subsidy is 'trade distorting'. It is possible in principle, therefore, that measures intended primarily to boost consumption of biofuels might fall foul of WTO rules.

This could occur indirectly and invisibly (because governments are inhibited from providing certain subsidies because of the rules) or directly and very visibly (because a subsidy scheme that exists is ruled by the WTO's Appellate Body to breach the rules). Three elements must in practice be present for the latter to occur: a subsidy must contravene the rules; a WTO member must suffer a measurable loss as a result; and it must launch (and persist with) a complaint.

As this sequence has not yet occurred, there is much speculation over what WTO rules do, and do not, allow. In principle, though, a country with non-prohibitive tariffs that applied a subsidy to the consumption of biofuels produced anywhere (ditto the raw materials) would be vulnerable only to a challenge from oil exporters – which would make an interesting case! It is the combination of a willingness to subsidise biofuels but an unwillingness to liberalise trade that creates vulnerability to WTO challenge.

[5] In cases where the subsidy to biofuels applies equally to domestically produced and imported goods it does not count as a restriction.

3. Economic, growth and poverty impacts

The TORs for this work request a consideration of key policy and strategic considerations for national decision makers related to poverty and pro-poor growth in biofuels production. These include:

- The economics of biofuels production, and impacts on the agricultural sector, including adaptation costs
- The poverty and equity dimensions of biofuels production, including land access, economics opportunities in different biofuels feedstock systems, the accessibility of biofuels supply chains, prospects for value addition, and the overall winners and losers in a scenario of biofuels expansion.

The TORs indicate the very wide range of poverty and pro-poor dimensions in the biofuels debate. It is difficult to generalise about the impacts of biofuels on poor people because the effects of: different feedstocks / production systems; varying downstream (transportation) costs; existing (non-biofuel) crop production and processing patterns; and patterns of land holding systems and sizes. In this section we will deal with each of these issues in turn, in the subsequent conclusions and recommendations section we draw out the winners and losers drawing on three scenarios of biofuels production (Malawi, Indonesia and Brazil).

3.1 Lessons about the impacts of biofuels on land access

In many parts of the world there are debates about the impact of cash crops on access to land by poor people. In many ways biofuels are not different from other cash crops in these debates. However, it is possible that the sheer speed at which biofuels expansion may occur will generate new pressures on land tenure arrangements. Will biofuels expansion impede or improve poor people's access to land under different biofuels scenarios?

In the case of sugarcane, much of the evidence is from Brazil. The current land arrangements for sugarcane are in part a reflection of historical arrangements from the expansion of sugarcane plantations in the 19^{th} and 20^{th} Centuries. However, evidence suggests that access to land for poor people continues to be reduced under biofuels production. This is due to the economies of scale sought by producers and subsequent land concentration.

Palm oil for biodiesel is also placing the spotlight on land access, ownership and use. Evidence from South East Asia – especially Malaysia and Indonesia – suggests that biofuels production is making improvements in land administration (particularly overlapping customary and formal titling) increasingly important. On a positive note, Potter (2001) suggests that in some cases where land rights are not recorded, palm oil expansion could strengthen claims to land.

In the case of Jatropha, because there is not yet evidence from large-scale production (for example impact of the 200,000 ha under outgrower production in Malawi has not been evaluated) it is not yet clear whether there are opportunities to avoid competition with existing higher potential land by cultivating in low potential areas.

The important factors in assessing the impact on land access for poor people are:

- Whether the crop is perennial or annual and whether it can be grown in combination with other crops – flexibility in land use has strong implications for land leasing and rental markets and the requirements of tenure arrangements;

- How far the feedstock can be grown on degraded land or used to revitalise degraded soils – if crops like jatropha can be produced on degraded land, conflict over land is likely to be reduced in the short-term, though in the long-term, as soils improve, new claims on land may emerge.

Policy implications:

The rapid expansion of biofuels is likely to generate increased conflict over land rights and utilisation. The prioritisation of improvements to land policies and land administration systems will be important to maximise the extent to which poor smallholder farmers, particularly those with insecure or customary tenure, can benefit from biodiesel production. The rapid expansion of biofuels may provide the pressure for land administration to become such a priority. As Potter (2001) argues – where land rights are not recorded, palm oil could strengthen claims to land by poor people and create an increased drive towards equitable land tenure arrangements.

3.2 Lessons about economic opportunities in biofuels production

Notwithstanding the differences between different production systems, feedstocks, historically patterns of wider agricultural production and poverty levels, the economics of biofuels production show us that in general:

- Economies of scale are important in biofuels production (though relatively less important in the production of feedstock than in the processing);
- In all current biofuels production systems, feedstock is the largest cost of production;
- Biofuels production can be complementary to other types of agricultural production and create linkages and multipliers; and
- Biofuels production requires a significant labour force.

These four issues are particularly important for the capacity of biofuels to generate livelihoods opportunities for poor people and to stimulate pro-poor economic growth.

Economies of scale in biofuels production. Evidence from the largest producers of biofuels (Brazil, US, EU) suggests that economies of scale are important for biofuels production that can compete with fossil fuels. The implication is that, in general, biofuels production is better suited to larger commercial farms and plantations. Small scale farmers face obstacles in trying to access supply chains – they trade off high transportation costs getting crops to processing plants with selling through middlemen. At processing plants they have to time delivery to fit daily plant capacity and meet plant standards. Either way, small producers are price-takers.

Given these constraints, the likely avenue by which small producers will access supply chains will be outgrower schemes or cooperatives. Evidence in Indonesia shows that small producers supported through outgrower schemes fare significantly better than independent producers. This implies a need for good market integration and coordination (Zarrilli 2006). Whilst in Indonesia outgrower schemes are not a specific government policy, in Brazil, in the smaller oil seeds sector, the government has introduced policies to support access by small farmers to supply chains. It has imposed limits on the amount of feedstock that biodiesel producers can procure from family farms in order to provide preferential access to small farmers (Smeets 2006).

Producers also benefit more if production and processing are linked so another alternative policy is the promotion of cooperative processing systems.

The feedstock is the largest cost of production. This applies to both ethanol and biodiesel.[6] For bioethanol the cost of the feedstock is often over half the total cost of production and for biodiesel the cost can be up to three quarters of the overall cost (OECD 2006). This makes all biofuels production sensitive to price fluctuations in the feedstock because feedstock makes up a larger proportion of the total cost. The implication for producers is that there will be constant downward pressure on prices.

The result will be pressure on producers to reduce production costs. The main mechanisms for doing this are difficult or risky for small producers – introduce improved varieties, switch away from diversified production systems to monocropping, move to larger land holdings to achieve economies of scale, and shift to increasingly capitalised production. For example, in the case of Brazil, selection of improved varieties for sugarcane and investment in irrigation have helped to improve yields but the benefits of these have mostly been felt on plantations. Other mechanisms, namely increasing labour productivity without increasing wages, are likely to be detrimental to poor households. This presents a serious challenge to identifying pro-poor biofuels production systems. More research is needed on the applicability of technologies that can increase feedstock outputs in developing countries, such as the use of double-cropping systems that can increase stalk to grain ratios for use in cellulosic biofuels.

Expanding biofuels production can create linkages and multipliers in the broader agricultural sector. Zarrilli (2006) identifies a series of synergies between biofuels and wider agricultural production. In the case of sugarcane evidence Brazil shows how sugarcane producing regions stimulate rather than compete with food crops for two reasons: First, additional income is generated through agro-industrial activities related to sugarcane and this 'capitalises' agriculture and improves the general conditions for producing other crops; and second, the high productivity of cane per unit of land enables a significant production of cane, with a relatively small land occupation.

Other potential linkages will emerge with future technological developments, however, we know little about the potential for new crops such as Jatropha or new systems such as cellulosic production to contribute to pro-poor multipliers in agriculture and the wider rural economy. Given that what we already know about sugarcane production for ethanol more research is required to see if other emerging crops will fare better.

Employment generation through biofuels expansion. Table 3.1 shows some current and projected labour requirements of biofuels production. Biofuels currently generate or will generate a significant number of jobs. For example, de Keyser and Hongo estimate that replacing fuel imports for transportation in Tanzania with domestically-produced biofuels would generate 300,000 jobs – equivalent to 1 job per hectare under biofuels production. Almost all of these jobs will be in rural areas, which is good for rural economic growth but there are caveats:

- The more profitable biofuels systems are labour intensive and generate less employment. In countries that are more advanced in production, employment is decreasing. For example, between 1992 and 2003, the total number of employees in sugar cane production in Brazil fell by one-third (Smeets *et al* 2006).

[6] This is particularly the case for biodiesel where the processing technology is simple and cheap – though this may change in the future with the introduction of new, more complex processing technologies.

- Production is highly seasonal and in Brazil the ratio between temporary and permanent workers is increasing.
- Jobs in on-farm production are likely to be unskilled and poorly paid (because the feedstock prices will be forced down to reduce costs).

In terms of different feedstocks, oilseeds are more amenable to job creation because they can be profitable under a labour-intensive production system and that government policies can be introduced to support labour-intensive production (for example the Brazilian government regulation regarding the amount of oilseeds that processors purchase from family farms). The policy implications here are that governments should support a focus on feedstocks that are profitable under labour-intensive farming methods and that generate wider economic linkages and, on plantations / processing plants, the identification of additional work beyond the biofuels production and processing season (Worldwatch Institute 2006).

Table 3.1 Employment in Biofuels Production

Country	Current (no of people)	Additional jobs in the future (no of people)
US (ethanol only)	147 – 200,000	
Brazil (ethanol)	500,000	
France		25,000 by 2010
Colombia		170,000 by approx 2010
Venezuela		1,000,000 by 2012
China		9,000,000 in the long term
Sub-Saharan Africa		700 – 1,100,000

Source: Worldwatch Institute (2006)

3.3 Lessons about opportunities in biofuels processing

Most of the world's poor people live in rural areas and are engaged in agriculture. In the previous section we reviewed the opportunities that might emerge in agricultural production as a result of biofuels expansion and found significant challenges for poor small farmers in the developing world. In processing there are prospects for pro-poor growth but it is not clear how far developing world governments will be able to take up these opportunities. This is for a number of reasons, including:

Infrastructure is critical. Whilst transportation costs are not generally the largest factor in overall production costs, the location of different parts of the supply chain can influence the cost-effectiveness of the system. The scale of the transportation system is a key factor in the cost of transportation: Water, rail and pipeline are most cost-effective. Many countries in Africa do not have navigable waterways, nor functioning railways or pipelines - significant investments would be needed to make processing (and even production) cost-effective.

These and other infrastructure investments could inhibit biofuels expansion. Given that biodiesel is easier to transport than bioethanol as it uses the same infrastructure as existing uses of its feedstock, this suggests that in countries with weak infrastructure, biodiesel production may be more appropriate than ethanol. Research on new technologies, such as pelletisation and drying might be a promising way of reducing transport costs for both biodiesel and bioethanol, but more research on the applicability of these systems in developing countries is needed.

Evidence from Brazil indicates that economies of scale in the size of plant used have been vital in bringing operating and capital costs below those of the feedstock (E4Tech 2006) and in making ethanol competitive against petroleum fuel. Tripling of plant size has been shown to decrease prices from $0.29/L to $0.23/L (Whims 2002). However, large-scale production systems have high capital cost implications (for example large storage tanks cost around $500,000 for a 25 thousand barrel tank, IEA 2004) that may be unaffordable for poor countries who do not already have liquid fossil fuel infrastructure.

Another crucial aspect of infrastructure is the flexibility of production and processing arrangements. Experience from Brazil and research in China indicates that flexibility of sugar plants to switch between sugar and ethanol production enables producers to adjust to sensitive market signals for sugar and energy (Gnansounou *et al* 2005) – so there is some element of path dependency in the selection of feedstocks. Countries which do not already have some sugarcane production experience or are unable to adapt existing cane processing infrastructure will struggle to compete in the biofuels market with those that have existing, adaptable industries. Countries that don't have large existing oilseed sectors will not benefit from the lower transportation costs.

Production costs are sensitive to how by-products are used. An important factor in the efficiency of Brazil's ethanol industry is the use of waste 'bagasse' for combined heat and power, enabling electricity production for plant processes and sale of electricity to other industries. The use of by-products also appears to be essential if bioethanol is to reduce greenhouse gas emissions (Farrel 2006). Glycerine, a by-product of biodiesel production and an ingredient in many foods and pharmaceuticals, can be worth between $0.05-0.10 per litre of biodiesel – a significant proportion of production cost (Kojima and Johnson 2005; Francis *et al* 2005), although markets can quickly become saturated, so countries should not rely on by-products for long term cost effectiveness. Nevertheless this offers potential in many African countries, which are mostly importers of glycerine.

The implication for developing countries is that they need some level of diversification in their economy in order to take advantage of biofuel processing by-products. Many developing countries are heavily dependent on natural resources, particularly agriculture, and have only limited manufacturing capabilities. However, even small and specialized economies such as that of Malawi do have small industries so, for example, there would be capacity to use glycerine by-products in Malawi's small pharmaceutical industry. It remains unclear whether by-products could kick start economic diversification, or a diversified economy already needs to be in place.

Technological progress is likely to significantly decrease costs. New feedstocks such as cellulosic ethanol could have costs below those of grain ethanol production in 2010-2020 timeframe. They may already be cheaper on cost per tonne greenhouse gas basis (IEA 2004). Processes for producing biodiesel are much simpler than those for producing bioethanol, so changes in processing technology are expected to occur mainly in ethanol production. This may have implications for long-term biofuel development plans in developing countries and implications for policies that support technology transfer for biofuels production.

Centralised production systems are not necessarily more efficient than decentralised systems. Biofuels production systems tend to be smaller and more decentralised than those of oil. In terms of different feedstocks, biodiesel production facilities tend to be more widely dispersed and smaller than bioethanol production systems, because a wide range of feedstocks can be used and producers can extract oil on site. Ethanol production plants in the US tend to be bigger than those in Brazil (which has three times more production plants for a similar production capacity) because grain can be stored for longer periods. There is a shorter operational season in Brazil and transportation costs are higher relative to the rest of the production process. Whilst decentralised systems for processing are likely to have a greater impact on rural poverty than centralised systems, it is difficult to see how, in developing countries, even decentralised systems will be able to generate year-round employment. Jobs are likely to be temporary and low-paid.

3.4 Challenges for achieving biofuels expansion

There are two sets of challenges for achieving biofuels expansions some of them relate to on-farm and off-farm technical processes and policies whilst other are linked to international policies. The former are reviewed in Box 3.1.

Box 3.1 Major Adaptation challenges

On-farm

- **Institutional structures:** adapting to fit production models that allow economies of scale. Large-scale systems are often economically favoured, so smallholder farmers might need to organise into cooperatives and/or outgrower schemes to allow access to markets.
- **Environmental impacts:** increased/decreased soil fertility; water pollution; downstream effects such as the draining of peatlands
- **Technology:** Access to farm technology which helps increase yields (e.g. the Brazilian experience suggests that this can be achieved through the selection of better varieties and irrigation (E4Tech 2006));
- **Changes in land use affecting:** access to land; effects of biofuels on cost of land which are currently poorly understood
- **Need for flexibility** to changes in the prices of feedstocks and to changes in the prices of inputs

Off-farm

- **Employment patterns:** Employment patterns are expected to change as biofuels sectors grow. Much work in the biofuels sector is non-skilled, but requirements for skilled labour are likely to increase.
- **Investment:** Biofuel processing and distribution infrastructure can require substantial up front investment
- **Need for flexibility:** Converting current production systems into biofuels production systems (e.g. existing legacy of sugar processing plants in Caribbean countries could be a constraint (E4Tech 2006)); Flexibility within processing plants is also a constraint (e.g. many Brazilian plants are designed to switch between sugar and ethanol production which allows adaptation to price changes).
- **Adapting regulations:** Changing regulation to suit efficient production processes will be needed in some cases. E.g. in some countries efficiency gains through co-generation is not an option because producers are not allowed to sell into the grid (E4Tech 2006)

In terms of adaptation challenges **on-farm**, much of the evidence regarding biofuels, particularly ethanol production, suggests that large-scale production systems are likely to be favoured given economies of scale. Adaptation on small farms will be most difficult and the role of cooperatives and other producer organisations is not well understood. This is a subject for future research. In the case of **off-farm** how far existing agro-industry will be able to transform to biofuels production, and whether public or private investment will support this, is similarly poorly understood.

Future investments could come from a variety of sources. In this regard, the TORs require some analysis of how far adaptation challenges are reflect in newly proposed international action plans. Box 3.2 gives an example of the prospects for support under Kyoto. There is significantly less to say about other international frameworks (Annex 3).

Box 3.2 Implications of the Kyoto Protocol for biofuels adaptation

Because biofuels have the potential to reduce greenhouse gas emissions, the Kyoto Protocol's Clean Development Mechanism (CDM) offers potential for funding biofuels projects in developing countries. However, owing to political compromises over what should and shouldn't be included in the CDM, this potential is limited by the design of CDM rules and procedures, which largely restricts access by the Least Developed Countries and bypasses smaller producers in those countries. For example:

- Biomass projects (a common type of CDM project) are generally large in scale and related to grid-based power systems. Their geographical spread is also limited, with most projects in larger developing countries and few in Africa.
- Rules for land-use related projects in the CDM are restricted to include only afforestation, reforestation and certain biomass related processes (such as methane capture from biodegradation) while the EU Emissions Trading System (EU ETS), the largest functioning carbon market, does not accept land-use projects.
- Small farmers are less able to access the carbon market because they lack expertise in implementing complex methodologies, ex-post payment systems mean there is a lack of up front funding for projects and investors are less interested in smaller projects with high risks and long timescales. Small-scale methodologies with simpler requirements and processes for bundling projects have been developed to address some of these issues, but there is currently no small scale methodology for liquid biofuels, and only one large scale methodology based on use of waste cooking oil for biodiesel (CD4CDM 2007).
- Despite their potential for bringing sustainable development benefits (a core aim of the CDM) biofuels projects are less attractive to investors because of high abatement costs, difficulties in proving additionality for projects and difficulties in calculating reduced greenhouse gas emissions of projects (Bakker 2006).

Negotiations over the next phase of the Kyoto Protocol (post-2012) are considering options for sector wide approaches to the CDM, meaning that developing countries could benefit from finance from developed countries for putting in place biofuels policies. However perverse incentives could arise, discouraging developing countries from putting in place legislation on biofuels because of rules over 'additionality' under the CDM[7].

There are alternative carbon markets outside of the Kyoto Protocol that show potential for supporting moves towards biofuels production in developing countries. These voluntary markets are smaller, but tend to focus on smaller projects aimed at reducing greenhouse gases and alleviating poverty. However, the quality of projects, in both environmental and social terms, can also be very variable, implying a need for more universal standards, an issue currently under consideration by the UK Deparment for Environment and Rural Affairs (Defra).

The sections above show how many different dimensions there are to analyse when seeking to understand the impact of biofuels expansion on agricultural growth and poverty. The net implications are exceedingly difficult to draw out and, once identified, are meaningless without context. Conditions vary from place to place and national level analysis would be required to make further recommendations – this follows in the conclusion with levels drawn from scenarios developed in Annex 3. It is clear though that many of the problems that emerge from biofuels are not unique to biofuels but are challenges that have faced agricultural development policy for many decades. However, given the potential rate of increase of biofuels production, it is possible that

[7] Additionality is the requirement that CDM projects must bring about greenhouse gas reductions that are additional to those that would have happened in the absence of a project.

the sub-sector may provide a new impetus and urgency to efforts to solve some old problems. Having returned to some old problems in agricultural development, in the next section, on food security, we ask whether biofuels constitutes a new challenge to achieving food security, or whether current analyses are simply a return to an old Malthusian food supply problem.

4. Back to Malthus? Debates about Food Security and Biofuels

Nowhere are opinions regarding biofuels more divided than in terms of their potential impact on food security. Whilst de Keyser and Hongo (2005) argue that biofuels production presents a win-win situation for developing countries by creating rural jobs and increasing food security, other commentaries raise concerns about the implications for world hunger resulting from biofuels expansion (Monbiot 2005, Brown 2006). They suggest the adoption of biofuels could result in a humanitarian disaster, that biofuels will result in *starving the people to feed cars*. Thus, Mayat (2007) and Gidley (2007) claim that in Mexico, tortilla prices have increased by up to 400% as a result of maize being diverted to ethanol production in the US. In order understand the validity of concerns regarding biofuels and food security, three critical questions must be explored:

4.1 Will land for biofuels compete with land for food production and reduce the availability of food?

Malthusian arguments about capacity are increasingly a part of the biofuels debate. Chaturvedi (2006) suggests population growth and increased demand for both biofuels and food will put extraordinary pressure on the land. Monbiot uses examples of the significant land requirements in the UK of a switch to biofuels. However, examples from parts of the developing world, where there are large areas of suitable land, and conditions for biomass production are up to five times as good as the UK (Johnson *et al* 2006) are more useful. Thus, de Keyser and Hongo (2005) estimate that in Tanzania around 300,000 ha out of a total of 4.6 million ha currently under crop, would be required to match current fuel imports. Across the border in Malawi, where population is much denser, the competition for land is much greater. However, in the case of Malawi, biofuels are not expected to totally displace oil-based fuel. Rather, they will be an alternative or a complement to it within a wide range of alternative renewable sources of energy. Koonin (2006) estimates that biofuels could supply 20-30 per cent of global demand in an environmentally responsible manner without affecting food production.

The extent that biofuels create competition for land and crowd out food crops depends on the biofuel crop in question. Section 3 has already shown how sugarcane in Brazil exhibits high yields and stimulates wider crop production. In the case of sugarcane in sub-Saharan Africa, Johnson *et al* (2006) argue that land requirements are also minimal but this is not proven. However, other biofuel feedstocks are show significantly lower yields than sugarcane in Brazil (see Table 4.1). The policy conclusion is that efforts to increase land and labour productivity in developing countries are critical if biofuels are to avoid competing with the use of land for food staples.

Table 4.1 Typical yields by region and crop, circa 2002 (litres per hectare of cropland)

	US	EU	Brazil	India
Ethanol from				

Maize (corn)	3100			
Common wheat		2500		
Sugar beet		5500		
Sugar cane			6500	5300
Biodiesel from:				
Sunflower seed		1000		
Soybean	500	700		
Barley		1100		
Rapeseed		1200		

Source: IEA (2004)

There are energy crops, e.g. Jatropha, that are not edible and therefore do not directly compete with food crops. This is also true for the second generation of biofuels technologies such as lignocellulosics that use woody crops as feedstocks. Although these technologies are not yet commercially available, they will be soon (Dufey, 2006). Synergies between biofuels and food crops have been discussed in Section 3. Moreover, there is an additional dimension to the biofuels-food security equation given changing consumption patterns – the debate may be more fuels versus feed than food (de la Torre, 2006).

Zarrilli concludes that the evidence suggests that '*all these developments indicate that the risk of competition between crops for food as opposed to crops for energy may be less serious than perceived at present'* (p. 20). We agree with this conclusion but suggest that existing critical barriers to increasing land and labour productivity in all parts of agriculture must be overcome if developing countries are to take advantage of biofuels opportunities.

4.2 What might be the impact on food prices in developing countries of a global increase in biofuels production and consumption?

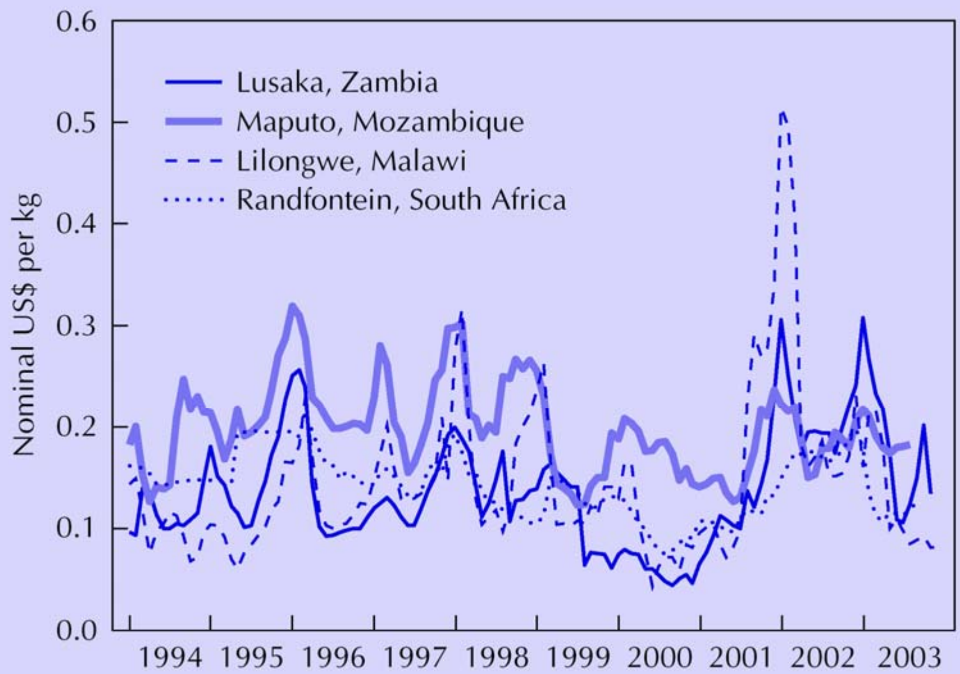
In many developing countries, most poor people are net consumers of food – even on farms in rural areas. So, food prices are as important as food availability. At present evidence that biofuels are leading to food price increases is only circumstantial (Mayat 2007, Gidley 2007). Analysis of variation in world grain prices suggests world prices of major grains have continued to decline in real terms (World Bank 2006) and there 'is no evidence of any recent increase in world price variability for grains' (p. 17).

Of the three main staples – rice, wheat and maize - only maize is currently used for ethanol production. The prices of these grains tend to move together, indicating that they are relatively good substitutes. So, at a global level at least, consumers are likely to respond to any shortage in the supply of maize or increase in its price by increasing consumption of rice or wheat. Whether rice and wheat prices will subsequently rise is less clear. However, given that there is an imperfect transmission of world prices to domestic markets (Hazell *et al* 2005), households in parts of Africa and Latin America may not easily adapt to new market conditions and switch to rice or wheat consumption. Thus, staples markets need to work better so that rice and wheat can quickly take the place of maize consumption if maize is diverted into ethanol production.

Staple food prices depend not only on variation in production but also on levels of stocks at global and national level. The World Food Crisis in 1973-4 was precipitated by a combination of poor harvests and the reduction of global grain stocks through large USSR purchases. Could a rapid increase in biofuels production following by a production shock could generate a food security crisis on the same scale as 1973? Recent years have seen critical changes in the stockholding policies of large countries. China, the EU and the US (together 69% of the world's grain stocks in 2005) have reduced stocks (Mitchell and Le Vallee 2005). '*As stocks decline, prices may become more vulnerable to sharp upward swings if there are climatic shocks or rapid shifts on global demand*' (World Bank 2006: p. 20). The latter effect could result from biofuels.

It is also important to distinguish between shorter and longer term impacts on food prices (Zarrilli 2006). In the short term, an expanding global biofuels market is likely to increase commodity prices for staple food crops such as maize and sorghum that are also used in biofuels production. Other staples are likely to follow this trend. However, we know that there will be downward pressure on prices in the longer term and cheaper oil may offset these negative effects that occur in the short-term.

It is very difficult to disaggregate the impact of biofuels on world prices from other factors (change in food consumption demand, supply constraints in remote rural areas, production shocks due to global environmental change or HIV/AIDS). In Southern Africa, there is a continuing downward trend in maize prices, but very high levels of variation (Figure 3.1). However, the importance of food prices suggest that research into changing prices and stocks, and their inclusion in food security early warning systems (EWS) will be critical in enabling governments and donors to prepare for food price shocks that cause acute food insecurity.



Source: Mozambique and Zambia: wholesale maize prices from Ministry of Agriculture; Malawi: retail maize prices from Ministry of Agriculture; South Africa: wholesale white maize price data from SAFEX, Randfontein.

Figure 3.1 Wholesale Maize Prices (US$/kg) in Southern Africa, 1994-2003

4.3 How might biofuels production, in the United States in particular, affect future aid flows, particularly food aid?

Our TORs ask us to assess the possible implications of expanded biofuels production on foreign aid flows. In the US cheap energy has been a cornerstone of US economic growth policy for over a century. In the context of rising petroleum prices and increasing demand for oil in countries with rapidly growing economies (for example China and India) US policy is increasingly unsustainable and it has set new targets for increased biofuels production (Shapouri, 2002). One of these is the "25 by 25" target – the goal of which is to supply 25% of United States' energy use from renewable resources by 2025. There are significant federal and state incentives for biofuels production – for example the USDA Credit Commodity Corporation Bioenergy Programme and ethanol tax credit of $0.53 / gallon. There are also cash incentives to producers of ethanol and biodiesel for incremental production.

However, current US foreign aid is heavily dependent on US agricultural surplus production. Aid is used to manage surpluses and stocks and the farm bill continues to reflect these priorities. The result is a foreign aid programme that is very heavily focused on food (either distributed or monetised) and is supported by a unique consortium of farmers, shipping interests and NGOs. Given current subsidies for maize production for biofuels, the impact on US aid quantities and policies need to be watched closely. If the use of maize for biofuels results in US aid policy switching to monetary aid, then there is scope for more innovative and flexible approaches to aid programming by USAID. However, this switch is likely to result in a breakdown of the farmers / shipping interests / NGOs coalition. With decreased support for foreign aid there may be subsequent reductions in the US Aid budget.

5. Environmental Impacts of Biofuels

Although the environmental impacts of biofuels are heating up the policy debates - with very differing views among those involved -, the available experience with biofuels – with the exception of Brazil and the US - is still very limited. While the production and trade of biofuels can result in several environmental impacts, both negative and positive, these tend to differ widely. This section provides a generic description of the key potential environmental impacts, providing examples where these are available, and briefly discusses some policy implications.

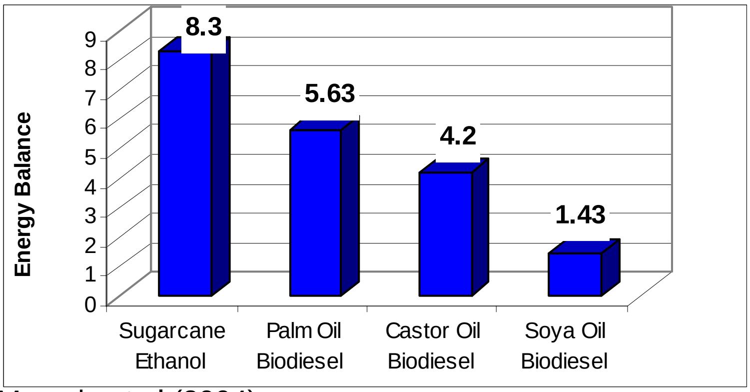
5.1 Expansion of the agricultural frontier

Environmental impacts must be considered in relation to the current land use, i.e., if the cultivation of energy crops replaces intensive agriculture the effects can range from neutral to positive; if it replaces natural ecosystems the effects will be mostly negative (WWF, 2006). In Brazil, that new sugarcane expansion might involve sensitive areas. Pressure not only comes through expansion of biofuel feedstock but the displacement of other crops into protected areas (Dufey *et al*, 2007). Whilst environmental legislation in Brazil is well advanced, lack of enforcement is a widespread problem. Elsewhere, e.g. Malaysia and Indonesia, forest conversion has been linked to oil palm production. Indonesia has 14-15 million hectares of land allocated to and cleared for the development of oil palm plantations, but which have not been planted yet. Expansion of new palm oil plantations for biofuels production therefore should be prioritised towards those areas to avoid new forest conversion (Kehati-Sawit Wath 2006). For newer energy crops such as Jatropha there is no evidence so far that those plantations are linked to deforestation or ecosystem destruction in southern Africa (Biofuelwatch, 206).

5.2 Energy Balances, emissions and air quality

The energy balance is the amount of energy required to produce one unit of biofuel compared to the energy contained in the same unit of biofuel and is highly variable (Figure 5.1), both in terms of feedstock energy content, inputs to production/processing and by-products from processing. In general, tropical energy crops have higher energy content than those produced in temperate zones (IEA, 2004) but woody energy crops used with new technologies have the best energy balances of all (Becker et al, 2003).

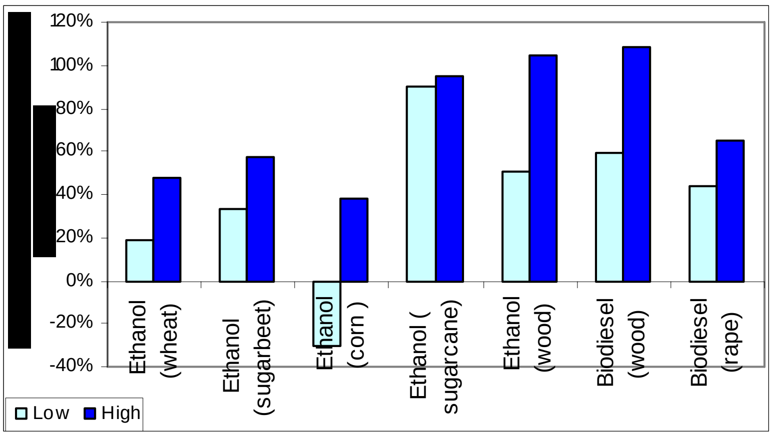
FIGURE 5.1: ENERGY BALANCE OF BIOFUELS IN BRAZIL



Source: Macedo et al (2004)

Available evidence suggests there is considerable variation in GHG savings from biofuel use depending on the type of feedstock, cultivation methods, conversion technologies, and energy efficiency assumptions (see Figure 5.2). The greatest GHG reductions can be derived from sugarcane-based bioethanol and the forthcoming 'second generation' of biofuels such as lignocellulosic bioethanol and Fischer-Tropsch biodiesel. Maize-derived bioethanol, on the other hand, show the worst GHG emission performance and, in some cases, the GHG emissions can be even higher than those related to fossil fuels. Chemical inputs, such as nitrogen fertilisers can also have a significant impact on greenhouse gas emissions. New research on reducing inputs, for example through the intercropping of nitrogen fixing soy beans with perennials, could help reduce inputs and make certain biofuels feedstocks more competitive in greenhouse gas terms.

FIGURE 5.2: GHG REDUCTIONS FOR DIFFERENT BIOFUELS



Source: E4 Tech, et al 2005

Fires are frequently used to clear fields for feedstock plantations resulting in greater air pollution. Sugarcane pre-harvest burning occurs in China (Woods and Read, 2005) but in Brazil (Sao Paolo state), new regulations prohibiting pre-harvest burning means this practice has been gradually decreasing (Dufey et al, 2007). In palm oil producing countries such as Malaysia and Indonesia, fires are prohibited but burning is still used for land clearing (Kehati-Sawit Wath 2006) with implications for air pollution in neighbouring countries in Southeast Asia (Clay, 2004).

Processing may also involve air pollution, especially the burning of fossil fuels to process heat and power (WWI 2006, Foster 2006). In Brazil, bagasse is used instead to generate an energy surplus which is then used in other sectors (Macedo, 2005). Regarding the combustion of biofuels in engines, although there are variations in emissions depending on the type of feedstocks, blends and the technology of the engine, most studies agree that biofuels can substantially reduce most pollutants (e.g. particulate, CO_2 and sulphate emissions) compared to fossil fuels. Finally, the transport of the energy crops and the biofuels also generates air emissions.

5.3 Soil and water management

Water use is a serious concern especially in arid and semi-arid regions where water is scarce and highly variable throughout the year. Some feedstocks, for example, sugar cane require lots of water (WWF, 2006) compared to others (e.g. Jatropha) which are drought-resistant crops. Water quality and effluent run-off problems – regardless of whether the crop is irrigated or rain-fed – by agrochemicals and sediments is also a problem – but not a unique biofuels problem. It has been argued that palm oil, for instance, due to its scale, may be the most polluting rural industry in Southeast (Kehati-Sawit Wath 2006). The processing of energy crops for biofuels also utilises water and though new conversion plants offer options for controlling water pollution, existing processing facilities, can cause discharges of organically contaminated effluent.

Impact on soil are another environmental concern but again not unique to biofuels. There are important differences between annual and perennial energy crops and in rural areas in developing countries where so much depends on recycling crop wastes and manure rather than use of the external inputs, biomass production could lead to dramatic declines in soil fertility and structure. Perennials like jatropha have been linked with soil restoration and are particularly efficient in soil coverage (Kartha, 2006).

All in all, biofuels cultivation, refining, combustion and transport can result in significant environmental problems, which are likely to become more acute as biofuels production and trade expand. The related impacts of this expansion on the agriculture frontier are a big concern. One of the main driving forces behind biofuel development is the benefit of reduced GHG emissions. However all the positive effects this benefit could risk being lost if the expansion of energy crops leads to higher CO_2 emissions due to further deforestation. Other key environmental impacts that need to be carefully addressed include those on the quality and quantity of water and on air quality. More rigorous research is particularly needed on lifecycle analysis of different Jatropha and Palm Oil production systems in relation to potential environmental impacts.

In policy terms, the available experience shows that the introduction of appropriate technologies, regulations and standards and, importantly, a proper enforcement of them, can help to mitigate most of these problems. Policies should also promote investment in environmentally friendly farming practices and technologies. In the context of poor developing countries, these policies should include adequate access to technologies and credit.

6. Priorities for Research and Policy Recommendations

This analysis of the impacts of biofuels expansion on agricultural growth and poverty reduction has highlighted many uncertainties about what will happen to global markets and prices and the opportunities that this may offer for poverty reduction in developing countries and among poor people. Various (sometimes contradictory) policy recommendations have been made throughout the paper, including:

- Address critical constraints / challenges to current agricultural production and agricultural growth
- Make staples markets work better to enable switching between the main staples (maize, rice and wheat) as maize for biofuels production increases
- Reduce agricultural support regimes for biofuels in the north to avoid penalising developing countries who already have restricted access to OECD markets
- Invest in improved land administration systems to deal with conflicting claims emerging under biofuels expansion
- Improve market coordination
- In poor countries invest in biodiesel which generates more labour, has lower transportation costs and simpler technology.
- On plantations and in processing mills identify additional non-seasonal sources of work to avoid highly seasonal employment in biofuels
- Improve storage infrastructure (especially in ethanol feedstocks) to lengthen the processing season.
- Invest in feedstocks that reflect existing domestic production patterns and thereby reduce costs
- Decentralise processing capabilities to have the greatest impact on rural employment, incomes and economic diversification
- Centralise processing capabilities to achieve cost-effectiveness through economies of scale.
- In food insecure countries / regions, focus biofuels investment on non-staple food crops.
- Set quotas for feedstock procurement to ensure small producers have access to supply chains.
- Provide support for small farmers to increase productivity to cope with downward pressure on biofuels producer prices – for example through improved varieties.
- Invest in biofuels feedstocks with higher yields that result in less competition over land.
- Invest in biofuels feedstocks that can be cultivated on marginal lands and have net benefits for soil rehabilitation.
- Invest in biofuels feedstocks that generate the best multipliers with the wider agricultural and rural economy
- Ensure enforcement of regulations, standards and appropriate technologies to improve the contribution of biofuels production to climate change mitigation.

This list includes many potentially contradictory messages. This is because it is very difficult to distil net recommendations from biofuels research that will be appropriate for different countries. We agree with Kojima and Johnson's (2005) assessment that:

> *Biofuels should be integrated within a broader context of investment in rural infrastructure and human capital formation. Low-income countries should assess whether the underlying conditions for a successful biofuel programme exist or could be developed in the near-term, including infrastructure and essential public services* (2005: 3)

Our scenarios (Annex 3) do generate lessons and more specific country level policy recommendations.

Scenario 1: Biofuels production in a net energy-importing country - Malawi
Whilst maize production accounts for a massive proportion of total agricultural production in Malawi, prospects for ethanol production from maize for export to northern markets are limited. Maize and sugar are not competitive on world markets and any increase in prices owing to biofuels will be short and not long-term. Transportation costs are high. At present, options for smallholder farmers to engage in jatropha production appear very limited. There has been some expansion of biodiesel production but mainly among former tobacco growers through outgrower schemes.

In policy terms, making biofuels work for poor people in Malawi would require:

- improved market coordination;
- investments in transportation;
- decentralised processing capabilities;
- improved storage to reduced the seasonality of employment in biofuels;

None of these challenges are unique to biofuels but are ones which donors and the Government of Malawi have been grappling with for some time. Whether opportunities in biofuels will enable further progress to be made is not clear. A focus on non-staple food feedstocks will lessen the impact on staple food prices in Malawi (see the next section on food security). Other small, poor and landlocked countries that are currently heavily dependent on a poorly-performing smallholder agriculture sector are likely to require similar policies.

Scenario 2: Biodiesel production for EU consumption in Indonesia
Biodiesel production is currently putting the spotlight on land administration issues in Indonesia. At present, there are three types of palm oil producers who could benefit from increased biodiesel demand in the EU. Increasing openness in oil palm fruit markets in recent years has allowed direct sales to mills by smallholders and stimulated growth in the smallholder sector. However, different types of smallholders are likely to win or lose in different ways. Some independent growers, mainly former plantation staff or wealthier local entrepreneurs, have been able to grow high yielding varieties but others still struggle to access markets. Palm oil price increases in the short term are likely to benefit smallholders, but this may not be sustained given increased competition with prices of soy oil and palm oil grown in other areas (e.g. West Africa, South America). Countries likely to have similar experience include Malaysia, Phillippines and Nigeria.

In policy terms, making biofuels work for poor people in Indonesia would require:

- a continued focus on biodiesel which requires fewer economies of scale, can draw on existing transportation systems and uses crops that Indonesia has long-term experience of producing and processing;
- decentralisation milling to reduce producer transportation costs in remote areas;
- improved land tenure for smallholder farmers to avoid rapidly emerging conflicts of customary and commercial land and usufruct rights;
- support to small farmers – for example quotas for mills that encourage them to buy from smallholders.

Scenario 3: Domestic and export ethanol production in Brazil
Ethanol production from sugarcane has created many jobs in Brazil. Other benefits have included multipliers to the wider agricultural sector. However, increasing economies of scale and land concentration have meant that benefits of ethanol production for small land owners have so far been limited and large farmers and

industrialists have benefited more from the expansion of the industry. Employment figures should be considered with caution, as there are large differences in the quality of work and wages between regions and between different parts of the production process. A high rate of migrant labour is employed and low skilled jobs dominate the industry. Countries likely to have similar experiences include South Africa and parts of Latin America.

In policy terms, improving the benefits of biofuels for small farmers would require:

- continued investment in biodiesel which, on the whole, is more pro-poor than ethanol production, does not depend so much on economies of scale, has lower transportation costs and is already a smallholder activity;
- continued pro-smallholder policies – for example quotas for procurement of feedstock from family farms.

What does all this mean for future research? Rather than present an inventory of technical research questions, we propose a focus on country level policy research. There are some important global level data gaps and priorities – for example tracking biofuels and food staples prices and stocks and the inclusion of this data into early warning systems for food security, or identifying mechanisms by which climate change mitigation funds might be used to support 'clean' biofuels production processing, or how WTO negotiations might affect biofuels markets and developing countries. On the whole, however, what is required is more country by country analysis. Without this it will not be possible to identify patterns of appropriate feedstocks, production systems, processing and marketing opportunities, and government roles that will maximise the impacts that production could have on rural livelihoods and poverty. Donors have significant roles to play at both global and national level with technical and policy support.

References

Albán M.A and Cárdenas H., forthcoming, 'Biofuels Trade and Sustainable Development:– The case of Biodiesel in Ecuador' International Institute for Environment and Development (IIED), London

Bakker, S. J. A. (2006) 'CDM and biofuels: Can the CDM assist biofuel production and deployment?', Energy Research Centre of the Netherlands (ECN), The Netherlands

Becker K. and Francis G. 2003 'Bio-diesel from Jatropha plantations on degraded land' Department of Aquaculture Systems and Animal Nutrition, University of Hohenheim available at: http://www.unihohenheim.de/~www480/docs/publish/jatropha_on_degraded_land.pdf (accessed 02/07)

Biofuelwatch (2006) 'Country Study 1: Green Gold for Southern Africa? Jatropha plantations in Malawi and Zambia'. United Kingdom: Biofuelwatch. http://www.biofuelwatch.org.uk/background4.php

Brown, L.R. (2006) 'Starving people to feed the cars' *Washington Post*, 10 September 2006.

CD4CDM (2007) 'CDM pipeline overview, March 2007', UNEP Risoe Centre for energy, climate and sustainable development, Roskild, Denmark

Chaturvedi, S. (2006) 'Opportunities for biofuels in select Asian economies: Emerging policy challenges' in International Centre for Trade and Sustainable Development *Linking Trade, Climate Change and Energy: Selected Issue Briefs* www.ictsd.org

Chirwa, E.W. (2004) Access to Land, Growth and Poverty Reduction in Malawi. *University of Malawi, Chancellor College*

Clay, J. 2004 'World Agriculture and the Environment' Washington, DC: Island Press. 570 pp.

De Keyser, S and Hongo, H. (2005) 'Farming for Energy for better livelihoods in Southern Africa – FELISA' Paper presented at the PfA-TaTEDO Policy Dialogue Conference on The Role of Renewable Energy for Poverty Alleviation and Sustainable Development in Africa, Dar-es-Salaam, 22 June 2005.

De la Torre, D. and Ugarte, D (2006) 'Opportunities and Challenges of Biofuels for the Agricultural Sector and Biofuels for the Agricultural Sector and Food Security of Developing Countries Food Security of Developing Countries' Power point presentation at the Expert Meeting on Participation of Developing Countries in New Dynamic Sectors for World Trade: Review of the Energy Sector Adjusting to the New Energy Economy Geneva November 30, 2006. Geneva: UNCTAD. http://r0.unctad.org/ghg/events/EnergySector2006/Daniel%20de%20la%20Torre%20Ugarte.pdf

Dufey A. 2006 'Biofuels production, trade and sustainable development: emerging issues', International Institute for Environment and Development, London.

Dufey A., Ferreira M and Togeiro L. (2007) 'Capacity Building in Trade and Environment in e Sugar/Bioethanol Sector in Brazil' Report by the International Institute for Environment and Development (IIED). London: International Institute of Environment and Development.

E4Tech (2006) 'Brazil: UK: Africa Partnership on Bioethanol', scoping study Technical analysis Study by E4tech (UK) Ltd. United Kingdom: OST

E4TECH *et al* (2005) 'Feasibility Study on Certification for a Renewable Transport Fuel Obligation', Final Report

FAO (2000) "The Energy and Agriculture Nexus", Environment and Natural Resource Working Paper 4, Annex 1. Available at http://www.fao.org/docrep/003/X8054E/x8054e00.HTM

Farrell, A, E, Plevin,R, J, Turner, B, T, Jones, A, D, O'Hare, M, and Kammen, D, M (2006) 'Ethanol Can Contribute to Energy and Environmental Goals' Science 311 (5760), pp. 506 - 508

Foster G, 2006 'Biomass Study – Maize from South Africa Prepared as input to the study of Dutch imports of Biomass Final report', November, available at: http://www.bothends.org/strategic/061211_Biomass%20case%20study%20South%20Africa.pdf

Francis, G, Edinger, R and Becker, K (2005) "A Concept for Simultaneous

Gidley, R. (2007) 'As biofuels boom will more go hungry' at http://www.enn.com/today.html?id=12345

Gnansounou, E., Dauriat, A. and Wyman, C.E. (2005) 'Refining sweet sorghum to ethanol and sugar: economic trade-offs in the context of North China' *Bioresource Technology* 96 (9): 985-1002.

GTZ (2005) Liquid Biofuels for Transportation in Tanzania: Potential and Implications for Sustainable Agriculture and Energy in the 21st Century, Study commissioned by the German Technical Cooperation (GTZ)

Hazell, P., Shields, G and Shields, D. (2005) 'The nature and extent of domestic sources of food price instability and risk' Paper presented to the workshop 'Managing Food Price Risk Instability in Low-Income Countries' February 28 – March 1, 2005, Washington, DC.

IEA (2004) 'Biofuels for Transport: an International Perspective'. Paris: International Energy Agency.

IPC-REIL (2006) 'WTO Disciplines and Biofuels: Opportunities and Constraints in the Creation of a Global Marketplace' *IPC Discussion Paper*, October.

Johnson, F, Seebaluck, V., Watson, H., and Woods, J. (2006) 'Bio-ethanol from sugarcane and sweet sorghum in Southern Africa: Agro-industrial development, import substitution and export diversification' in International Centre for Trade and Sustainable Development *Linking Trade, Climate Change and Energy: Selected Issue Briefs* www.ictsd.org

Kartha S, (2006) 'Environmental Effects of Bioenergy' in Hazell P. and Pachauri R. (eds) *Bioenergy and agriculture: promises and* challenges Focus 14, Brief 5 of 12, December. Washington, DC: International Food Policy Research Institute. www.ifpri.org

Kehati-Sawit Wath (2006) 'Report Research Indonesian Path Toward Sustainable Energy: A case study of developing palm oil as biomass in Indonesia'. Indonesia: Sawit Watch. http://www.bothends.org/strategic/061211_Biomass%20case%20study%20Indonesia.pdf

Knight, P. (2007) 'Energy Crops have begun a revolution for agri-business in Brazil' *World Ethanol and Biofuels Report* 5 (12): 243-248.

Kojima, M. and Johnson, T. (2005) 'Potential of biofuels for Transport in Developing Countries', World Bank Energy Sector Management Assistance Programme (ESMAP), Washington, DC.

Koonin, S. (2006) 'Getting Serious About Biofuels' *Science* 311 (5760): 435, 27 January

Koplow, D (2006) 'Biofuels: At What Cost? Government Support for Ethanol and Biodiesel in the United States', report prepared by Earth Track Inc. Geneva, Switzerland: The Global Subsidies Initiative (GSI) of the International Institute for Sustainable Development (IISD).

Macedo *et al* (2004) Assessment of Greenhouse gas Emissions in the Production and Use of Fuel Ethanol in Brazil, NIPE/INCAMP, S.P.

Macedo I.C (Ed) 2005 'A Energia da Cana de Açúcar - Doze estudos sobre a agroindústria da cana-de-açúcar no Brasil e a sua sustentabilidade' UNICA

Mayat, M. (2007) 'Opening Pandora's Box: GMOs, Fuelish Paradigms and South Africa's Biofuels Strategy' African Centre for Biosafety, www.gmwatch.org/ Accessed 02/2007

MFC (2007) Mali Folk Centre website: http://www.malifolkecenter.org/ (Accessed 02/07)

Mitchell, D. and le Vallee, J. (2005) 'International Food Price Variability: The implications of recent policy changes' Paper presented to the workshop 'Managing Food Price Instability in Low-income Countries' Feb 28 – Mar 1, 2005, Washington, DC.

Monbiot, G. (2004) 'Feeding Cars not People' The Guardian 22 November 2004, available at: http://www.monbiot.com/archives/2004/11/23/feeding-cars-not-people/

NBB (2007) National Biofuels Board website: http://www.nbb.org/ (Accessed 02/07)

OECD (2006) 'Agricultural Market Impacts of Future Growth in the Production of Biofuels, Directorate for Food, Agriculture And Fisheries', Committee for Agriculture, Working Party on Agricultural Policies and Markets. Paris: Organisation of Economic Commerce and Development.

Pereira, A (1983) "Employment Implications of Ethanol Production in Brazil.", International Labour Review 122(1): 111–127.

Pimental, D. and Patzek, T.W. (2005) 'Ethanol production using corn, switchgrass, and wood; biodiesel production using soybean and sunflower' *Natural Resources Research* 14 (1): 65-76.

Potter, L. (2001) 'Agricultural intensification in Indonesia: outside pressures and indigenous strategies'. Asia Pacific Viewpoint 42:307-326.

Read, P. (2004). 'Good news on climate change' Abrupt Climate Change Strategy Workshop Press Release. http://www.accstrategy.org/goodnews.html

RFA (2007) 'Building New Horizons: Ethanol Industry Outlook 2007'. Washington DC: Renewable Fuels Association

Shapouri, H. (2002) 'Economic Impacts and Value-Added Benefits of Biofuel in the United States' Presentation to the International Convention on Biofuels-Driving India's Future, November 7-9, 2002, New Delhi.

Smeets et al, E, Junginger, M, Faaij, A, Walter, A, and Dolzan, P (2006) 'Sustainability of Brazilian bio-ethanol', study by Copernicus Institute - Department of Science, Technology and Society for SenterNovem, The Netherlands Agency for Sustainable Development and Innovation, The Netherlands, Utrecht

TERI (2005) 'Liquid Biofuels for Transportation: India country study on potential and implications for sustainable agriculture and energy', Study commissioned by the German Technical Cooperation (GTZ)

UNCTAD (2006) 'The UNCTAD Biofuels Initiative'. Switzerland: UN Conference on Trade and Development. http://r0.unctad.org/ghg/projects/Biofuels%20flyer.pdf (Accessed 02/07)

UPME (2006) 'Biocombustibles en Colombia' power point presentation by the Ministry of Mining and Energy of Colombia at the Seminario Internacional sobre Biocombustibles, 23 – 25 April 2006, Brasilia, Brazil. http://www.olade.org.ec/biocombustibles/Documents/PDF-20.pdf (Accessed 02/07)

USDA (2007) USDA Agricultural Projections to 2016. Office of the Chief Economist, World Agricultural Outlook Board, U.S. Department of Agriculture. Prepared by the Interagency Agricultural Projections Committee. Long-term Projections Report OCE-2007-1, 110 pp.

Veiga Filho, A, A, Ramos, P (2006) The Brazilian National Alcohol Program and Evidente of Concentration in Sugarcane Production and Processing. Informações Econômicas, v.36, n.7, july 2006. pp. 48-61.

Vermeulen, S. and Goad, N. (2006) Towards better practice in smallholder palm oil production. Natural Resource Issues Series No. 5. International Institute for Environment and Development. London, UK.

Von Braun, J. and Pachauri, R.K. (2006) The Promises and Challenges of Biofuels for the Poor in Developing Countries, IFPRI 2005-2006 Annual Report Essay, IFPRI, Washington, DC

Whims, J., (2002), 'Corn Based Ethanol Costs and Margins', Attachment 1, AGMRC, Kansas State U., http://www.agmrc.org/corn/info/ksueth1.pdf. Accessed 02/2007

Woods, J and Read, P, (2005) 'Arguments for Bioenergy Development' in Policy Debate on Global Biofuels Development, Renewable Energy Partnerships for Poverty Eradication and Sustainable Development, June 2005, Partners for Africa/Stockholm Environment Institute.

World Bank (2006) *Managing Food Price Risks and Instability in an Environment of Market Liberalisation,* World Bank Agriculture and Rural Development Report No 34499-GLB, Washington, DC.

Worldwatch Institute (2006) 'Biofuels for Transportation: global potential and implications for agriculture and sustainable energy in the 21st century', Final Report prepared by Worldwatch for GTZ, Washington: Worldwatch Institute.

WWF 2006 'Sustainability Standards for Bioenergy', World Wide Fund for Nature (WWF) Germany, November

Zarrilli, S (2006) 'Trade and Sustainable Development Implications of the Emerging Biofuels Market' in International Centre for Trade and Sustainable Development *Linking Trade, Climate Change and Energy: Selected Issue Briefs* www.ictsd.org