5. Implications of increased use of bioenergy

There is a growing perception that bioenergy offers a range of advantages over other energy sources. These include increased rural income and reduced levels of poverty in developing countries, restoration of unproductive and degraded lands and promotion of economic development. By contributing to increased energy security, bioenergy also has strategic implications, particularly for oil importing countries. Finally, it has the potential to help reduce greenhouse gas emissions, which are a global concern.

There are, however, challenges to be overcome before the full potential of bioenergy can be realized. A number of problems associated with biofuel production, especially regarding large-scale operations, have been highlighted. In order to minimize bioenergy development strategy risks, it is important to fully analyse the different aspects of bioenergy and wood energy development:

- rural development, equity and poverty reduction;
- land and forest management, and biodiversity;
- food and forest product prices;
- greenhouse gas emissions and air quality;
- water availability;
- energy prices and energy dependence.

Bioenergy development entails both benefits and negative effects (Box 6). Given the range of interactions, the potential benefits and costs of investments in bioenergy should be assessed on a case-by-case or country-by-country basis.

There are many factors involved in increasing production of energy from biomass. Crop type and productivity are among the most important. In a 2004 study based on IEA data, different agrofuels were compared in terms of arable land requirements for a given amount of energy production. The results showed that soybean requires almost 12 times as much arable land as sugar cane. Other potential liquid biofuel sources fall somewhere between these two extremes. Corn, for example, requires twice as much land as sugar cane, while oil-palm requires about 30 percent more land.

Even more striking, is the answer to the question: “How much arable land would be required to replace 25 percent of the transportation energy from fossil fuels with energy from liquid biofuels?” The answer is 430 million hectares for sugar cane – 17 percent of the world’s arable land – and 5 billion hectares for soybean – 200 percent of the world’s arable land (Fresco, 2006). It is therefore not realistic to conceive of biofuels as totally replacing fossil fuels. Biofuels need to be viewed as one potential source of energy to be used in combination with others.

BOX 6

Potential benefits and negative effects of bioenergy development

Potential benefits

- Diversification of agricultural output
- Stimulation of rural economic development and contribution to poverty reduction
- Increase in food prices and higher income for farmers
- Development of infrastructure and employment in rural areas
- Lower greenhouse gas emissions
- Increased investment in land rehabilitation
- New revenues generated from the use of wood and agricultural residues, and from carbon credits
- Reduction in energy dependence and diversification of domestic energy supply, especially in rural areas
- Access to affordable and clean energy for small and medium-sized rural enterprises

Potential negative impacts

- Reduced local food availability if energy crop plantations replace subsistence farmland
- Increased food prices for consumers
- Demand for land for energy crops may increase deforestation, reduce biodiversity and increase greenhouse gas emissions
- Increased number of pollutants
- Modifications to requirements for vehicles and fuel infrastructures
- Higher fuel production costs
- Increased wood removals leading to the degradation of forest ecosystems
- Displacement of small farmers and concentration of land tenure and incomes
- Reduced soil quality and fertility from intensive cultivation of bioenergy crops
- Distortion of subsidies on other sectors and creation of inequities across countries

Sources: FAO, 2000; UN-Energy, 2007; Perley, 2008

POVERTY, EMPLOYMENT AND PRICES

A number of studies have reported that biomass production for bioenergy will offer developing countries new income sources, thereby reducing poverty and enhancing food security. There are, however, many variables which determine whether the expansion of bioenergy has a net positive or a net negative impact on livelihoods. When small-scale farmers have the opportunity to produce biomass independently or through outgrower schemes, there may be net benefits. But there is a history of disputes. In Indonesia, the establishment of large palm oil plantations has been associated with alleged land grabbing and human rights abuses (Aglionby, 2008).

The extent of employment opportunities resulting from bioenergy development is dependent on the crop and system of production. The harvesting of crops such as *Jatropha curcas* is labour intensive and can generate jobs and incomes for rural people. On the other hand, the harvesting of bioenergy crops such as sugar cane do not use much labour and provide relatively few jobs for the rural poor. The significance of liquid biofuels in relation to employment has therefore been questioned (Biofuelwatch, 2007). It is likely that production of bioenergy will provide greater opportunity for employment than fossil fuel import, especially where import levels are high. The scale and nature of production systems are however, crucially important to employment generation.

Bioenergy developments have the potential of making energy available to rural populations with limited access to other energy sources, and this can promote economic development. The living conditions of poor households would be improved if bioenergy development led to a more efficient and sustainable use of traditional biomass (UN-Energy, 2007).

Social conflicts can be provoked by the introduction of large energy plantations supplying centralized conversion facilities. Conversion facilities should be located close to biofuel production sites to reduce transport costs and increase economic viability. It is possible that such arrangements could result in increased concentration of landownership and displacement of traditional farmers. With effective local planning, however, structures involving farmers as outgrowers can be developed, resulting in opportunities for smallholder investment.

Competition for land and agricultural products may increase food prices but could also have the effect of improving farmer income. Those producing the greatest surpluses would benefit, while net buyers would suffer more. The distribution of costs and benefits will depend on local circumstances, although the net effect on food security of increasing food prices may be negative in many cases. The greatest impact may be on the urban poor who do not have access to land to capture benefits from increased agricultural prices.

If prices of liquid biofuel crops rise significantly, farmers will tend to convert food croplands to energy crops. In the short-term, this could reduce food supply, and food prices would increase. However, farmers shift cultivation quite frequently, and crop decisions are based mainly on market prices and profitability. Higher food prices would increase the incentive to use land for food crops, so the market would act to restore the supply–demand balance. However, it must be stressed that an increase in food prices, even if only transitory, would affect the poor – especially in developing countries (Box 7).

LAND AND ENVIRONMENT

Land is a key factor in the production of bioenergy resources, and its availability varies among and within regions and countries. Extensive establishment of energy plantations may place limits on the availability of land for producing food and as a result, food security is a concern for some countries – particularly those with limited land resources and high populations.

Recent studies have shown that although significant global reserves of potential cropland exist, predictions for population growth and land-use competition

BOX 7

Food prices and bioenergy

Rosegrant *et al.* (2005, 2006) studied potential impacts of the growing demand for energy on real world food prices. They examined three cases within an aggressive liquid biofuel growth scenario, which assumed that total biofuel consumption would rise between two- and tenfold in specific countries or regions around the world, including China, India, Brazil, the United States and the European Union, and presuming that oil prices would stay high in real terms. The three cases were:

- continued focus on cereal-based liquid biofuels;
- a shift to wood-based liquid biofuels;
- increased use of cellulosic biofuels combined with improvements in agricultural practices.

The authors estimated that in the first case, real food prices would rise significantly by 2020 (see table). In the second, offsetting new development with wood-based fuels could reduce these increases somewhat. Combining cellulosic biofuels with agricultural improvements could result in the lowest possible price increases. Each of these cases suggests higher real crop prices in the future.

Each of the three cases would entail higher average prices in the global food marketplace, although changes at the country level would vary. These results are confirmed by other models, notably an analysis by Schmidhuber (FAO, 2006a), which found that the extra demand for biofuel feedstocks has resulted in increased global agricultural commodity prices.

An increase in food prices would have an impact on food security, particularly in countries where food is scarce owing to poor growing conditions or other environmental factors. A price increase for food commodities would also increase incomes in rural areas, potentially reducing poverty. Increasing the proportion of wood-based biofuels could help decrease the expected rise in food prices, but some cost increases must still be expected. It should be noted that, historically, real prices for food and agriculture have been declining, and a departure from this trend to meet biofuel demand may not be permanent (FAO, 2006a).

Expected rises in commodity food prices in three cases under an aggressive biofuels growth scenario (percent increase, 2005 to 2020)

Commodity	Continued focus on cereal-based biofuels	Shift to wood-based biofuels	Wood-based biofuels + agricultural improvements
Cassava	135	89	54
Sugar beet	25	14	10
Sugar cane	66	49	43
Oilseeds	76	45	43
Maize	41	29	23
Wheat	30	21	16

Source: Rosegrant *et al.*, 2006

suggest that reserves are not well distributed in relation to future demand. For example, some Asian countries with high populations appear to have no, or very limited, land available for bioenergy production (Risø, 2003).

In heavily populated Asian countries, however, agroforestry, the use of agricultural and forest wastes and efficient energy conversion technologies could provide significant amounts of bioenergy. Latin America, much of Africa and some forest-rich countries in Asia have large areas that could potentially be turned over to biomass production. Biodiversity is, however, threatened when large-scale monocultures are grown for energy purposes, even when non-forest land is used. The loss of pastoral lifestyles associated with shrinking grasslands, and the loss of feed production for domestic and wild herbivores on these lands, could also have significant negative economic and social impacts (UN-Energy, 2007).

In many developing countries, extensive degraded lands are being considered for expansion of bioenergy plantations. India, for example, is focusing on 63 million hectares classified as wasteland. They estimate that 40 million hectares are suitable for cultivating oil-bearing plants (Prasad, 2007). The planting of trees or other energy crops in such areas has been suggested as a way to reduce erosion, restore ecosystems, regulate water flows and provide shelter and protection to communities and to agricultural lands (Risø, 2003). To realize such benefits, however, the expansion of biofuel production will need to be accompanied by clear and well enforced land-use regulations, particularly in countries with tropical forests at risk of conversion to other land-uses (Worldwatch Institute, 2007).

There has been resistance to agrofuel projects because of the risks and potential conflicts they pose. In Uganda, for example, the public reacted negatively when the government granted a permit to a company to exploit the Mabira forests for planting sugar cane for agrofuels. Similar reactions to agrofuel projects have also been reported in Ghana and South Africa (GRAIN, 2007).

Forests in several countries have been replaced by crops intended to produce biofuels and this trend could accelerate if there are large increases in the demand for biofuels and bioenergy in general. The dynamics could change dramatically, however, if woody biomass becomes the biofuel feedstock of choice, and a future in which forests threaten farmland, rather than the opposite may be possible.

To ensure that sufficient cropland is available to produce food at affordable prices and to avoid loss of valuable habitats, it is imperative that land-use planning and monitoring be considered in bioenergy strategies. Possible scenarios for liquid biofuel development are outlined in Box 8 together with their likely impacts.

Potential negative environmental impacts related to large-scale increases in forest and bioenergy plantations include reduced soil fertility, soil erosion and increased water use. Intensive cultivation increases and concentrates water consumption, and in many countries, water is an increasingly scarce resource. Some agrofuel crops consume large quantities of water. In March 2006, the International Water Management Institute issued a report warning that the rush for liquid biofuels could worsen the water crisis in some countries. For example, in China and India where water resources are scarce, a large share of agrofuel

BOX 8

Scenarios for liquid biofuel development

The large-scale production of bioenergy requires extensive land areas, and there are concerns that first-generation liquid biofuel crops could affect food security and forest cover. To deal satisfactorily with land-use issues and their implications on forests, liquid biofuel production could be expanded under one or a combination of the following scenarios:

- **Turning degraded lands and/or lands currently dedicated to food crops over to bioenergy production (including wood energy).** This approach would not be expected to impact upon forests although it could affect food security, especially in the case of large-scale operations, unless productivity is increased and/or synergies between food and energy production are found.
- **Introducing liquid biofuel crops into forested areas.** This would result in deforestation and impact on biodiversity and other forest goods and services, and would increase greenhouse gas emissions. Wood-based industries could face reductions in raw material supplies, and the demand for construction materials and other wood products may be reduced. Wood availability for energy production may increase in the short-term.
- **Diverting wood produced from existing forests to energy production.** This would have an impact on income and management of natural forests and plantations and would increase competition for resources among wood users. Wood available to the forest industry could decline in the short-term and the costs of products may increase.
- **Increasing efficiency of wood use by optimizing processing and using wood residues and recovered wood to produce bioenergy.** Significant amounts of energy could be generated and negative impacts on forestry and agriculture would be minimized.

crop production depends on irrigation (GRAIN, 2007). This can reduce the water resources for food crops and have impacts on food security. Though, these impacts can be mitigated through good land-use planning and responsible management (FAO, 2006b).

There is also concern about an increase in air pollution if biomass combustion increases (WHO, 2006). In particular, wood combustion in installations with insufficient filters or incomplete combustion releases fine particulates that pose a health hazard. Some countries have burning device standards, but these may be compromised by low fuel quality (e.g. wet wood) and ineffective burning techniques. As there are major consequences to increased biomass combustion, many of which are interlinked, a holistic approach is necessary when setting targets and making policies to combat climate change (UNECE/FAO, 2007). Valuable time and effort is also devoted to fuel collection rather than more profitable pursuits and for these reasons the United Nations Millennium Project has set a goal of halving the number of households using traditional biomass for cooking by 2015.

Forest clearance

With increasing demands on land from first-generation liquid biofuel development, pressure on forests is likely to increase around the world. In many cases, the opportunity costs will be too high to prevent conversion of forests to the economically attractive land-uses that will emerge if bioenergy development continues its recent trajectory. Forest clearance will result where measures to protect and sustainably manage forests are ineffective or not upheld.

Loss of forest area will lead to carbon release and biodiversity losses. Ownership and use rights may also be affected where land is under traditional ownership or rights are not fully recognized. Soybean, sugar cane and oil-palm have all been associated with deforestation, which has contributed significantly to greenhouse gas emissions in countries where production of these crops has proliferated (GRAIN, 2007).

Recent studies have suggested that economic incentives to produce biofuels increasingly cause conversion of forest or grasslands, thereby releasing carbon dioxide stored in plants and soils through decomposition or fires (Searchinger *et al*., 2008). The significance of taking land-use change into carbon calculations for bioenergy development cannot be ignored. It has been estimated, for example, that if secondary forest is replaced with sustainably produced oil-palm, it will take 50–100 years to recapture lost carbon (Butler, 2007b)

Large areas of rainforest have been and are being cleared to make room for oil-palm plantations. The world's most significant areas of oil-palm plantation are in Indonesia and Malaysia. It has been estimated that approximately 17 to 27 percent of Indonesian deforestation may be explained by the establishment of oil-palm plantations, and in Malaysia the figure may be as high as 80 percent. In Indonesia, 3.6 million hectares of land are under oil-palm plantations and this figure is increasing by around 13 percent per year (FAO, 2007c). At the same time an average of 1.8 million hectares of forests are disappearing annually – equivalent to 2 percent of the national forest cover. This has not only caused large emissions of carbon dioxide into the atmosphere, but has increased the threat to several endangered species (UNECE/FAO, 2007).

Carbon dioxide emissions are particularly immense when oil-palm plantations are established on drained peat lands and, according to a study by Hooijer *et al*. (2006), 27 percent of oil-palm plantations are located in such areas. Carbon dioxide emissions from drained peat lands in Indonesia include 1 400 mega tons from peat land fires and 600 mega tons from decomposition of drained peat lands. This is estimated to equal almost 8 percent of global emissions from fossil fuel burning, and places Indonesia in third place in terms of global carbon dioxide emissions after the United States and China (Hooijer *et al*., 2006). There is evidence that bioenergy products, including some destined for export, contribute to this trend.

For example, significant amounts of palm oil are used for biodiesel production, primarily for use in Europe (Carrere, 2001; Colchester *et al*., 2006).

An increase in bioenergy use in industrialized countries could have widespread effects around the world. Currently, this is most likely for easily transportable liquid biofuels. With the advent of commercially viable liquid cellulosic biofuels, nations with abundant forest resources may be tempted to increase supply of bioenergy feedstocks, resulting in forest loss where sustainable management principles are not followed.

Large areas of degraded forest are also likely targets for the expansion of bioenergy plantations. Although not in pristine condition, such forests still maintain high levels of biodiversity and large amounts of carbon and may also provide important safety nets for local people in terms of food and materials production. Whether such areas can be sustainably managed for multiple goods and services including bioenergy production remains to be seen, but recent trends do not incite confidence.

In 2007, the Chinese State Forestry Administration (SFA) announced an initiative to develop two *Jatropha curcas* plantation bases in Yunnan and Sichuan Provinces for biofuel production. The SFA has since announced its intention to devote more than 13 million hectares of forestland to biofuels expansion, and the Yunnan Provincial Forestry Department plans to develop 1.3 million hectares of plantations by 2015 with the aim of producing four million tonnes of bioethanol and 600 000 tonnes of biodiesel annually (Liu, 2007). It is claimed that these plantings will be carried out on degraded forestlands and croplands, which have been estimated to amount to 4 million hectares in Yunnan Province alone. The southwestern areas of China have many forest areas with high biodiversity and land protection values (Perley, 2008).

Before implementation, countries need to assess greenhouse gas emissions and other environmental implications associated with various bioenergy alternatives in terms of a full life cycle – i.e. the full range of environmental impacts associated with production, including land-use change. The potential for bioenergy to reduce greenhouse gas emissions is well recognized. Relevant projects are well represented in the current global pipeline of actions to be funded under the Clean Development Mechanism (CDM) of the Kyoto Protocol. The CDM and other mechanisms should help overcome the financial barriers to carbon-efficient biofuel development, but because of complex rules and processes, access to the CDM itself by less developed countries is currently restricted (Peskett *et al.*, 2007).