Biofuels in Developing Countries

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Precise motives for promoting biofuels vary from region to region and country to country. The major motivation in petroleum importing countries such as Brazil, India, China, and most Sub-Saharan countries is increased energy security through reduced reliance on costly and unstable imported energy sources. In Africa, oil consumption increased 15% between 2002 and 2007 while expenditure tripled. Tanzania and Senegal spend about 40% of their foreign exchange earnings on purchasing oil products (personal comm., Tongola, Ibrahim. Biofuels in West Africa, COMPETE Workshop, Burkina Faso, 26 November 2007). Local production of biofuels for internal consumption could have substantial economic benefit in terms of foreign exchange savings. Brazil and most Sub-Saharan countries also view biofuels as potential options for creating rural employment.

Many developing countries have advantages over developed countries in the temperate zones in that biomass production potential is much higher and production costs can be lower. The tropics have also been targeted as having the more arable land area to meet the growing demand for biofuel crops (Field et al. 2008). As such the biofuel policies of developed countries such as the EU and USA are also partly driving and defining biofuel programs in the developing world, particularly Africa. The biofuel programs in many countries such as Ethiopia, Kenya, Madagascar, Mozambique, and Tanzania (and possibly others) are in part export-driven and prompted by investment from external agencies such as European companies (BP in Ethiopia, D1, Sun Biofuels, Sekab, to name but a few). The influence of external policies and export-driven biofuel production is less well defined in China and India. Whether biofuel production is driven

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box 15.1

Why biofuels?

There is a large global interest in finding alternatives to transportation fuels to substitute petroleum-based fuels. IPCC (2007) highlighted the potential for biofuels to meet the growing energy needs as well as contribute to GHG emissions reduction, especially in the transportation sector. Escalating oil prices and the uncertainty about sustained oil supplies have further added to the growing interest on biofuels. Much of the discussion to date has focused on the benefits of ethanol and biodiesel production in the US and Europe in terms of:

- *Foreign exchange savings by governments (by reducing the volume of fossil fuel imports)*
- *Improved energy security by reducing dependence on uncertain petroleum imports*
- *Mitigating climate change, where biofuels substitute fossil fuels and their related GHG emissions.*

While these benefits apply to most countries, the production and use of biofuels in developing countries have potential additional benefits including:

- *Promotion of rural development by production a locally generated form of energy for processing and transportation,*
- *Creation of rural employment and wealth*
- *Reduction of deforestation and land degradation, as biofuels also substitute for the energy current derived from wood.*
- *Multiple use crops can be reallocated for energy or food needs depending on changing local needs and priorities.*

by internal or external policies, markets - both domestic and export-will influence the type of biofuels grown, as well as potential local economic costs or benefits and, more generally, rural development.

In this chapter we review some of these issues including nascent biofuel policies in developing countries, the potential for biofuel production in developing countries in terms of the diversity of crops and available land, and the constraints to realizing that production potential. The social, economic, and environmental impacts of different models for biofuel production in developing countries are also explored. We finish the chapter by highlighting key research issues and emerging issues of biofuels in developing countries.

Emerging biofuel policies in developing countries

Some countries, both developed and developing, have already set targets for substituting or supplementing diesel and gasoline by biofuels, with proportions ranging from 5 to 20% to be met at various times within the period 2010-2030. Both developing and developed countries have, or are in the process of formulating biofuel policies to meet these targets, along with associated incentives, regulations and standards. Some examples of developing countries with biofuel targets are:

India. In 2006 the Government of India announced that it would make ethanol blending mandatory as of October 2006 – initially with a 5% blend (E5), rising to a 10% blend (E10) within a year, and E20 subsequently (Smith 2006)

Brazil. In Brazil, policy dictates that anhydrous ethanol from sugarcane to gasoline proportions vary from 20 to 25%. Biodiesel blending mandates are much lower, (3%), but are slated to increase to 5% in 2013.

South Africa. The biofuel draft strategy aims to achieve a biofuels average market penetration of 4.5 % of liquid road transport fuels (petrol and diesel) by 2013. Pricing will be linked to the BFP (basic fuels price), which is an import parity marker for local producer prices of fuels and is the basic element of fuels price regulation. The biofuels industry will continue to receive a percentage Fuel Levy reduction for all liquid biofuels that comply to agreed specifications.

Other. Zambia and Mozambique are currently developing biofuels policies and other African countries are in early stages of considering biofuels policies.

It is likely that many of these biofuel programs and projects are being launched without considering and enacting long-term policies. Yet, these policies will shape biofuel programs and the associated impacts (e.g. land use change, employment, land tenure, ecosystem and human health, air quality) in the years and decades to come.

Biofuels status and demand forecasts

There are large uncertainties in estimating the future demand for petroleum fuels as well as for that of biofuels. Projected demand for biofuels is estimated based on projections for petroleum oil fuel demand for the transportation sector for 2030 (IEA 2008), an assumed 10% mass rate of substitution of the petroleum by biofuels, and a diesel to gasoline ratio of 45.5% to 54.5%. Globally, 10.1 EJ of biodiesel and 11.7 EJ of ethanol are required to substitute 10% of the projected diesel and gasoline consumption by 2030 (Chapter 6, Ravindranath et al. 2009). Based on assumed mandates for biofuels current estimates are that developing countries will account for about 44% of global demand for biodiesel and 47% of ethanol demand.

IEA-WEO projects a very modest demand for biofuels by 2030 ranging from 1.7 to 2.0 EJ under the Reference Scenario and Alternate Policy Scenario, respectively (IEA 2006). However, when a 10% target for substitution of projected diesel and gasoline consumption for 2030 is considered, the projected global biofuel demand is 21.5 EJ, which is 8 times higher than the Alternate Policy Scenario projections of World Energy Outlook (IEA 2006). By contrast total oil consumption in Africa (for all purposes) was 6.3 EJ in 2007 (BP 2008).

There is uncertainty regarding sustainability of biofuel production in the face of changing climates. According to the projections made by IPCC (2007), agricultural production and food security are under threat due to climate change and variability, and this threat also holds for annual or perennial biofuel crops to be grown to meet the biofuel demands. Thus, there is a need for an improved understanding of all these issues to assess the potential sustainable biofuel production and its environmental and socio-economic implications in developing countries.

Feedstock crops

There is a greater variety of highly productive biofuel feedstocks that can be grown in tropical developing countries compared to those that can be grown in temperate, developed countries. For ethanol, these include sugarcane, a variety of starchy crops such as cassava, and grain crops such as maize, and sweet sorghum. A wide variety of oilseed crops, traditionally viewed as foodstuffs, (e.g. groundnuts, sesame and soybean) and several cooking oil production crops (e.g. cotton seed, oil palm, and sunflower) can be used for biodiesel production (Chapter 4, Connor and Hernandez 2009).

In many areas where food production should be given a priority over biofuel production to meet national food security requirements, inedible crops and a variety of non-food crops are already being used or explored for their biofuel potential. Conner and Hernandez (Chapter 4) note several potential perennial cellulosic and non-edible oil crops including trees and shrubs such as jatropha, several palms and indigenous Amazonian trees. The potential biomass/oil yields and quality of many trees and non-edible oil crops from the woodlands and arid lands of Africa are beginning to be investigated through various projects (e.g. the World Agroforesty Centre in collaboration with a European Commission INCO project "Competence Platform on Energy Crop and Agroforestry Systems for Arid and Semi-arid Ecosystems – Africa (www.compete-bioafrica.net). The trees *Pappea capensis* and *Ximenia caffra are* potential oilseed sources and indigenous to Southern Africa. In 2006, South Africa's Department of Mineral and Energy Affairs suggested that oil from their seeds may have potential for biodiesel production. An extensive literature and questionnaire survey by Sobey and Watson (2008) established that very few of their oil properties have been determined. The characteristic range of properties of those that have been assessed do not compare favorably with ranges for an ideal biofuel (Koerbitz, 2007).

Even for well recognized biofuel crops such as jatropha, there is surprisingly little information on the yield potential under different agro-climatic zones. The great potential currently being touted for jatropha is based on scanty evidence, calling for a systematic assessment and analysis of the potential of these so-called promising biofuel species in terms of their oil yields and quality, but also their production and input requirements across the agro-climate zones and soil types of the tropics. This is particularly important where cultivation is planned on marginal or waste lands.

Harvesting wild resources for biofuel production is risky. Trees are likely to be damaged by exploitive, unregulated harvesting practices, resulting in wide ranging detrimental environmental and livelihood impacts particularly for species that provide nutritious fruits and medicines for humans and animals. Exploiting the indigenous plants as feedstock for biofuels would need to include domestication programs to select for specific properties such as oil yields, quality, and content, as well as the ability to produce under managed systems so as to minimize the damage and exploitation of natural systems.

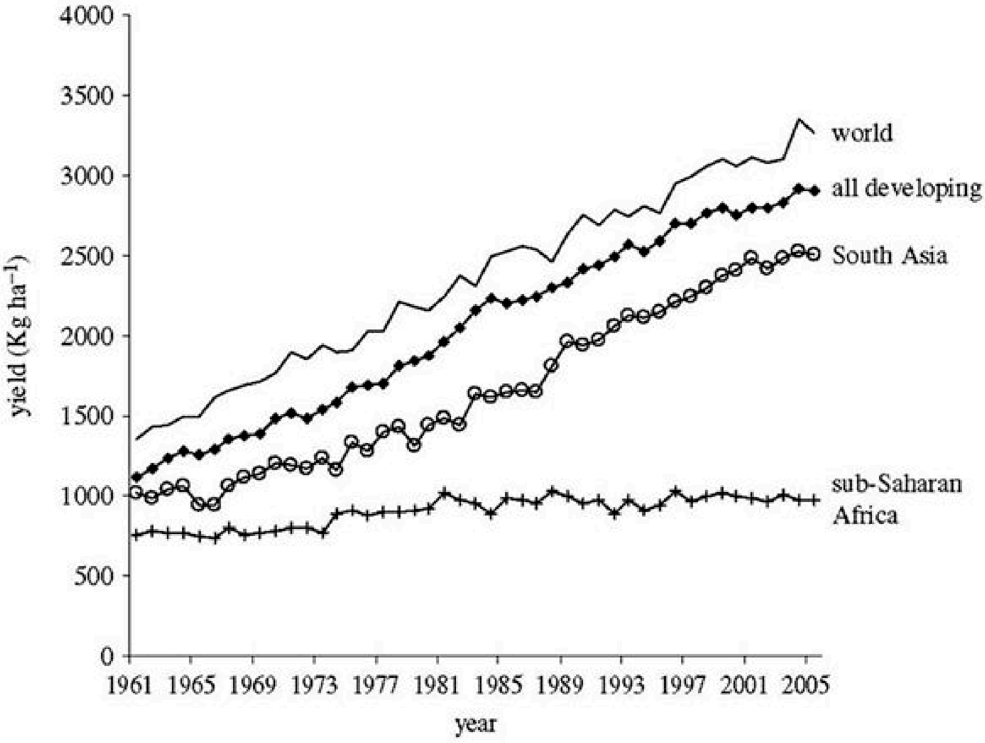
The present first-generation biofuels are produced by the processing of agricultural food and feed crops. Non-food crops have potential, though they still need research on their domestication and conversion into biofuel.

Land required for biofuel crops

Land required for producing the projected biofuel demand will depend on the choice of biofuel crops and the potential yields of ethanol or biodiesel and associated co-products, if any. An analysis by Ravindranath et al. (Chapter 6) on the land required for producing biofuel crops to meet 10% petroleum fuel substitution by 2030 shows that total land required varies depends on the feedstocks used. The least amount of land, 118 Mha, is required when palm oil and sugarcane are considered, whereas jatropha and maize crops at moderate yields require 321 Mha. These estimates fall within the range of other estimates presented in Chapter 16 (Bustamante et al. 2009).

Is there land available to grow these biofuels? Globally, according to FAOSTAT (2008), out of the 4.96 billion ha of available 'agricultural area', consisting primarily of cropped land and permanent pastures, the total arable land is about 1.42 billion ha, which is largely cropped area. Permanent meadows and pastures, which could potentially be used for biofuel crops,

Figure 15.1 Global trends in cereal yield by region 1961-2005. (Reprinted from Hazel and Wood, 2008).



box 15.2

Land required for biofuels

India

India has ambitious biodiesel plans; a 20% substitution target for diesel consumption projected for 2030 (62 Mt) by biodiesel (15.7 Mt). As a net importer of vegetable oil, the country is developing its biodiesel future with non-food oil feedstocks (i.e. jatropha and pongamia) grown on wastelands.

The land required to meet the target, assuming jatropha will meet 100% of the projected biodiesel demand and an average yield of 1.5 ton of oil ha^{-1} yr^{-1}, is estimated to be 10.4 Mha. This accounts for about 25% of the current estimated total wasteland area of 41 Mha (National Remote Sensing Agency 2006). These lands may require significant inputs of nutrients and the adoption of soil and water conservation measures for obtaining the desired yields.

It is also feasible to assume that farmers may convert currently cropped area to biofuel crops if the economics are attractive and if incentives are provided. Yields of major crops in India are about 50-67% of the global average (FAOSTAT, 2008). Additional land may become available, if yields of main crops such as rice, wheat, sorghum and pulses are increased to the global mean levels, though part of this productivity gain is needed to keep pace with increased food demand of a growing and more affluent population.

Though there seems to be sufficient land to meet the biofuel demand for India, several issues still need to be addressed including the costs of inputs to grow the biofuels on 'wastelands', the growing demand for food production, and the social implications of displacing area currently devoted to food production by biofuels. Additionally, food insecurity is high in India, thus biofuels must not compete for resources with food crops.

Southern Africa

Sugarcane is currently the world's most significant energy crop, with considerable potential not yet fully realized in southern Africa. Watson et al (2007) evaluated yields, area harvested, percent of sugar recovery, and length of vegetation cycle for sugar cane in southern Africa, and identified Malawi, Mozambique and Zambia as the best suited countries in the region for the crop. In the assessment, the authors considered whether a substantial increase in sugar cane production in these countries was limited by the availability of suitable land. To answer this, they delineated and filtered out land surfaces that fell within protected areas, slopes steeper than 16%, cultivated or wetland areas, areas already under sugar cane, and areas smaller than 500 ha. The suitability of the areas left over for sugar cane production was verified using climatic soil data.

The findings (Table 15.1) show that Mozambique (2338 ha) followed by Zambia (1178 ha) present the greatest prospects for expanding sugarcane production. Malawi (206 ha) lags a factor of 11 and 6 behind, respectively. Clearly, land is unlikely to be a limiting factor in harnessing sugarcane's bio-energy potential to create rural livelihoods and alleviate poverty, reduce dependence on imported energy sources, and offer new development pathways in the region. However, in some areas increased competition for water may emerge. Addition-ally, as with the case of India, food security priorities should be paramount in planning biofuel programs in this region.

account for 3.8 billion ha. Total land area required for producing biofuels to meet a 10% global petroleum fuel substitution scenario with first-generation biofuels would require 8-36% of current cropland (118-508 Mha), largely through conversion of pastureland. Moreover, total land area required for producing biofuels to meet the 10% petroleum fuel substitution scenario (118 -508 Mha) is relatively small, roughly 2-10% of the current global 'agricultural area'. However, regional and country level differences in land availability for biofuels crops are likely, with varying levels of opportunity costs, as illustrated by the the case studies in boxes 15.1 and 15.2.

Opportunities, constraints, and potential impacts

Biofuel production opportunities in developing countries are being fuelled by the apparent relative availability of land to grow the feedstock crops; however, a biofuel boom in these countries raises concerns about potential added social and environmental pressures. Possible impacts include increases in food prices and reduced food security in low income societies and environmental consequences resulting from land-use and land-cover change (e.g. greenhouse gas emissions and loss of biodiversity). These impacts are poorly understood, but seem to depend on the premise that biofuels production can be sustained at a reasonable level, and with transparent and fair market prices to allow appropriate investment.

Poverty and food security. About one billion people in the world are hungry or malnourished, with over half of them living in rural areas in South Asia and Sub-Saharan Africa (SSA) and dependent on agriculture for food and livelihoods (UN Millennium Project 2005; Hazell and Wood 2008). In South Asia there is sufficient per capita food production to feed the population but unequal distribution of food, resulting in pockets of hungry people; whereas in Sub Saharan Africa there is insufficient per capita food production to feed the population as a whole (Hazell and Wood 2008). There is potential to increase yields in both

Table 15.1 Areas suitable for sugarcane production remaining after successive filtering out of data, given in 1000 ha and as a percentage of country's area (Watson, 2007).

	Malawi		Mozambique		Zambia	
	1000 ha	%	1000 ha	%	1000 ha	%
Country area	9408		78409		74339	
Potentially suitable for sugarcane	742	7.9	4906	6.3	3546	4.8
Protected areas filtered out	595	6.3	4602	5.9	2433	3.3
Slopes > 16% filtered out	580	6.2	4530	5.8	2427	3.3
Crops & wetlands filtered out	316	3.4	3773	4.8	1726	2.3
Existing sugarcane filtered out	314	3.3	3771	4.8	1726	2.3
Areas < 500 ha filtered out	256	2.7	3470	4.4	1485	2.0
Unsuitable soils & rainfall filtered out	206	2.2	2338	3.0	1178	1.6

areas. South Asia realizes about 75% the global average yields of major food crops, while Sub-Saharan Africa realizes less than 30% (Figure 15.1).

Low and variable yields. Compared to other areas, agricultural yields in Sub-Saharan Africa are very low. While cereal yields in other areas depict a rising trend over the past 40 years, yields have been stagnant in Sub-Saharan Africa at around 1 t ha - one third of the global average (Figure 15.1). Low crop yields relate to degraded lands, inherent low soil fertility, nutrient depleted soils, and/or unreliable rainfall and lack of water.

Nutrient depletion from years of harvest without nutrient replenishment has been cited as one of the major factors affecting low yields and land degradation in Africa (Sanchez 2002; Stoorvogvel et al. 1993). For a host of reasons, small scale farmers in Africa lack the external inputs needed to raise crop productivity. Indeed, the lack of infrastructure, the absence of input and output markets, as well as lack of basic information on plant nutrient management, in many cases prevent the smallholder farmers of Africa from increasing food, feed, and biofuel production and from maintaining, if not improving, the fertility of the soil.

Water also limits crop yield. The bulk of SSA's agricultural production occurs under rainfed conditions, posing substantial risks to farmers and investors because of erratic rainfall patterns and temporal and spatial variability. Frequent short dry spells during the growing season reduce yields and also have an indirect impact, as farmers are less likely to invest in inputs and land management due to the high risk of crop failure. Unreliable rainfall leads to highly variable yields, which also poses a challenge for biofuel feedstock production. On the other hand, the new market opportunities through biomass energy production may trigger additional investments in water for agriculture to raise yields and moderate fluctuations.

Degraded lands as opportunities. Africa has been targeted as a region with abundant under-utilized land with the most potential of all the world's regions to produce bioenergy (Field et al. 2008). However, much of the land has soils and climate that limit crop production either because of low inherent potential or decreased potential as a result of land degradation. Only 6 to 11% of the soils in African have no serious constraints to be effectively managed (Hazel and Wood 2007), about 34% is of medium or low potential with at least one major constraint for agriculture, and 55% is unsuitable for agriculture. Studies in the 1990s (Stoorvogel et al. 1993) showed that land degradation in East and Southern Africa was primarily due to (i) high population density with continuous cultivation and low use of fertilizers (<12 kg ha on average) and (ii) water and wind erosion. In the equatorial forest zones, water erosion, leaching, reduced fallow and burning are major nutrient loss avenues (Buerkert and Hiernaux 1998). The decline in soil organic matter, results in reduction of essential plant nutrient retention, breakdown in soil physical structure, and limited water infiltration and storage capacity. All of these constraints to food crop production also pertain to production of biofuels and must be addressed if indeed Africa is to realize the potential for delivering on the demand for biofuels for local and export use.

All types of degradation require inputs to reverse the impacts and rehabilitate soil processes and ecosystem productivity. Reversal of physical degradation often requires physical, chemical, and biological inputs, as well as large inputs of human labor. Reversal of chemical degradation through application of mineral and/or organic inputs is consider-ed easier, faster, and cheaper than the physical rehabilitation of soils.

Failure to rehabilitate and utilize these lands for crop agriculture has been a matter of economics. Profitability margins in agriculture are low due to lack of domestic market infrastructure, trade barriers to international markets, and high marketing costs caused by poor roads (Rosegrant and Perez 1997; Oweis et al. 1999; Rosegrant et al. 2001; Moussa 2002; Diao et al. 2003). Poor governance, disincentives to profitable agriculture (taxes, rent seeking, land tenure arrangements) and the high level of risk discourage farmers to invest in labour and other inputs (Rockstrom 2004).

Recent efforts to rehabilitate soil fertility and realize an agricultural revolution in Africa through use of subsidized fertilizers and improved seeds combined with extensive agricultural extension efforts have shown doubling or tripling of cereal crop yields at local levels in 10 countries, with levels of production that could meet local food requirements (Sanchez et al. 2007). Malawi has doubled maize yields nationally in over the past 3 years (Denning et al. 2009) and has gone from a net food importer and food aid recipient to a net food exporter over this time period.

Such increases in yields, if scaled up across Africa, could address the hunger and malnutrition in rural areas without significant increases in the area of land under cultivation. Though a detailed country by country analysis is needed, this agricultural revolution might provide opportunities for biofuel production that does not compete with food crops for land.

Biofuel feedstock will grow on these lands if proper care is given to boost plant growth and maintain production through additional inputs. Some crops may have the potential to rehabilitate degraded lands in their natural environments. Jatropha, for example, can be used in soil reclamation and conservation (Spaan et a. 2004; Ogunwole et al. 2007). Whether jatropha grown for these services, and without inputs, would result in adequate oil yields needs substantiation.

The bottom line is that consideration of the use of so-called ‘degraded’ or ‘waste’ lands in Africa and elsewhere for production of biofuel feedstock cannot be de-linked from the need for increased food production. Increasing yields from either monocropping or integrated farming becomes a pre-condition for raising incomes in rural areas and consequent growth and development. Increasing yields will require systems that promote conservation of productive lands, rehabilitation of degraded soils, provision for and efficient use of nutrient inputs, conversion of rain water into moisture available for plant use, crop improvements that better utilize these inputs, and increasing human capacity and institutions to support these services. Assessments of the possible synergies, but also the potential competition for land, degraded or not, between biofuels and food are essential on regional, national, and even sub national levels before significant plans are developed.

Water availability and infrastructure for biofuel production. Feedstock production requires substantial amounts of water. To produce the biomass for one liter of biofuel, an average 2500-3500 liters of water is evaporated by crops (de Fraiture et al. 2008). Much of this water can be met with rainfall, where rainfall is abundant and reliable. But water demanding feedstock crops such as sugarcane often need irrigation. Compared to other regions in the world, the level of water resources development in Sub-Saharan Africa is low. Only 4% of agricultural production originates from irrigated areas and only one sixth of the irrigation potential in Sub Saharan Africa has been realized (Ward et al 2006). In many areas of Sub-Saharan Africa, water scarcity for crop production is caused by the lack of infrastructure to tap into water resources rather than an actual physical shortage (IWMI 2007). Develop-ment costs in irrigation are high, averaging $6000 USD per hectare in Sub-Saharan Africa compared to $1500 USD per hectare in South Asia (Innocencio et al. 2006). It is unlikely that farmers and governments will be able to afford large investments in irrigation for biofuel feedstock, unless significant returns are envisaged.

With the increasing demand for biofuels, a new group of investors has emerged, i.e. foreign companies buying or leasing land for feedstock production. For example, the Procana project in the Olifants basin in Mozambique foresees the development of 30,000 ha of irrigated sugarcane plantation for bio-ethanol (Agencia de Informacao de Mozambique 2007) and another investment proposal seeks to convert wetlands in the Tana Delta in Kenya into sugarcane for bio-ethanol (Economist 2007). Sugarcane cultivation is water intensive and these schemes will require substantial amounts of water, posing new challenges. Policies and regulations to ensure minimum flows in the rivers and lakes for environmental purposes, protection of riparian zones and wetlands are not well developed in most of SSA (Smakhtin et al 2004), with the exception of South Africa that has very progressive water laws (van Koppen 2005). Many river basins in Sub-Saharan Africa are transboundary, flowing through several countries. The negotiation and enforcement of water rights and international water treaties is a difficult process requiring a strong institutional infrastructure. Influential foreign or multinational companies with multi-million dollars investments at stake may tip the balance in their favor and small-holders and the environment may lose out on access to water.

Water use and water budgets at the landscape scale by other feedstock crops need to be studied more systematically across the agro-climatic zones, especially when such crops are to be established in large scale plantations. Would introducing jatropha in semi-arid areas, for example, result in a positive water balance through reduced soil evaporation (increased shading and self mulching) being higher than increased canopy transpiration? Will the establishment of tree plantations in biomes with low tree densities result in negative water balances and the loss of water flow to streams and rivers?

Impacts of climate change. The IPCC (2007), concluded that projected climate change is likely to lead to increased water stress, land degradation and reduction in crop yields, particularly in tropical and sub-tropical regions. The implications projected by the IPCC for the annual food crops as well as forest ecosystems could be extrapolated to bio-fuel crops which have not had studies dedicated to them. The key likely impacts of climate change which can be extrapolated are:

An increase in 5 to 8 % in arid and semi-arid land areas.

Decline in the agriculture yield due to drought and land degradation; by 2020 in some countries of Africa, yields from rain fed agriculture could be reduced by 50%.

Increased water stress for annual as well as perennial cropping systems in arid and semi-arid regions.

Thus, annual as well as the perennial bio-fuel crops are likely to be subjected to adverse impacts leading to reduction in yield. It is very important to recognize the importance of climate change and initiate research on assessment of its impact and for developing adaptation strategies for different bio-fuel crops in different regions of the developing world.

Environmental impacts of biofuel production. The environmental impacts of biofuel production includes local contamination (Martinelli and Filoso 2008) or reduction of water supplies, loss of biodiversity (Watson 2007); regional and transboundary air pollution problems (Martinelli and Filoso 2008) and global changes in net global warming potential through net emissions or sequestration of greenhouse gas emissions (Chapter 5, Menichetti and Otto Chapter 16, Bustamante et al. 2009).

An example from South Africa shows the needs for holistic assessments on the potential impacts of biofuel programs. Watson (2009) showed that using protected area databases to identify “no go” areas for feedstock production is not sufficient to safeguard biodiversity. Historically, the motivation for according protected area status over much of Africa was either that the land was unsuitable for commercial agricultural activities because the land was marginal, too steep, infested with malaria and/or sleeping sickness etc, or the land was needed to serve as a buffer between land claimed by the white colonists and land allocated for African use. Management practices within these protected lands, such as veld burning and culling animals, were not driven by considerations for biodiversity, but a focus on large mammals, trophy species and improving game viewing. These lands, therefore, only contain a limited, biased sample of the biodiversity in the arid and or semi-arid regions of the ten case study countries. A high proportion of valuable biodiversity (in terms of irreplaceability) is actually outside these official protected areas in the province of KwaZulu-Natal in South Africa (Watson 2009).

This chapter provides no additional review or examples for environmental impacts, but refers readers to the other relevant chapters in this volume. There is need to stress however that policies must be considered in early planning and development to consider the environmental concerns. Global conventions such as for biodiversity (CBD), climate change (UNFCCC), and desertification (CCD) should all be invoked and used to ensure local and global communities can benefit from biofuel production.

Infrastructure limitations. Current density and conditions of infrastructure in Sub-Saharan Africa limits the possibility of developing competitive biofuel programs for national distribution and export but at the same time provides opportunities for local development. Road density in Sub Saharan Africa now is less than that of India in the 1960s (UN Hunger Task Force Report 2005). Transport costs per kilogram of product in Sub-Saharan Africa are several times higher than most places, translating to diesel prices (at 2002 rates) of up to $1

box 15.3

Large-Scale Initiatives

Brazil. The biofuels industry in Brazil got underway on a large scale in the early 1970s, within the PROALCOOL Program (Dufey et al 2007; Goldemberg et al. 2008). Ethanol production in Brazil is primarily through commercial farming, with little input from local stakeholders. Sugarcane production jumped from 5.6 Mt in 1950 to more than 500 Mton per year in 2008 (Conab 2008). This large increase in production was primarily associated with the industry's own production and, to a lesser extent, independent suppliers. In 2008, only 45% of total yield was produced by independent suppliers on land that is rented to the industry (Conab, 2008).

The biofuels industry in Brazil has been propelled by appropriate government policy interventions and massive investment in infrastructure and research. The program was so successful that by the mid-1980's four out of every five new cars sold were ethanol only and by 1988 ethanol had overtaken petrol as the main source of transport fuel. However, the drop in global petroleum prices in the early 1990's, combined with a rise in global sugar prices, led to a shortage of hydrous ethanol (Chapter 1, Howarth et al. 2009). The government responded by passing a law requiring an 18-26% blend of anhydrous ethanol. By the late 1990's the government liberalized the ethanol industry by deregulating pricing. Flex-fuel vehicles (FFVs), which can run on pure ethanol or any blend of ethanol and petrol, now account for about 80% of all new cars sold in Brazil. The current policies supporting ethanol include the following: a 20-25% blending mandate; total value-added tax, excise and other duties are about half what they are for petrol; tax breaks for flex-fuel vehicles; low-interest government loans and reduced tax burdens along the entire production value chain; and licensing of biofuel producers to ensure quality standards are met.

The scientific and technological advances that contributed to the success of the ethanol industry included sugarcane crop improvements through breeding adaptation to different soil and climate conditions, shorter production cycles, better yields, and tolerance to water scarcity and pests. In production, new grinding systems were developed and the fermentation process adapted to use different microorganisms and enzymes to produce more ethanol faster. Wastes were turned into fertilizer (vinasse) and used to power steam turbines for electricity generation (bagasse). In consumption, flex-fuel cars were developed in order to create demand for ethanol biofuel. These advances were also a success public-private sector partnership story.

Brazil has several environmental and social challenges to address if it is to continue at the forefront of increasing its already significant production. Part of these problems are described in Smeets et al. (2008). However, it is important to highlight some that are crucial for the sustainable development of the ethanol industry in Brazil.

One of the main environmental problems is the annual burning of sugar cane leaves from April-May to October-November to facilitate harvesting by hand. The particulates and gases from the burning provoke a series of pollution problems from poor visibility to acid rain and high nitrogen deposition (Lara et al. 2001). The particulates also cause a significant increase of respiratory diseases, mainly among children and elderly people (Cançado et al. 2006). Under heavy pressure from society and government the State of São Paulo, where 50% of Brazilian sugar cane is cultivated, established a law that requires the cessation of all burning in mechanized areas with a slope lower than 12% by 2021 and in areas with a slope higher than 12% by 2031. In the State of São Paulo approximately 30% of the harvesting is currently done without burning (Conab 2008). More recently, an environmental protocol was signed by States representatives and most of the mills located in São Paulo aim to end burnings by 2014.

Social problems are also linked to sugar cane burning. Working and living conditions for the sugar cane harvesters are poor, leading to a series of health problems (Martinelli and Filoso 2008; Smeets et al. 2008). On the other hand, most of these workers are migrants from the poor northeast states of Brazil. The workers move to the Southeast region during the sugar cane harvesting period to work in the field. Mechanizing of harvesting will replace approximately 300,000 workers, half of the jobs located in the State of São Paulo (Conab 2008). Therefore, there is need for retraining and

USD per liter (World Bank Datasets 2002). These transport costs then affect other commodities that are essential for producing biofuels, fertilizer cost 2 to 4 times the international price (Sanchez 2002) and increased dramatically with the spike in oil prices in 2007. The current costs of transport are a major reason for the lack of availability and use of fertilizers in Sub-Saharan Africa and will also constrain the development of biofuels for regional and international export markets. In fact industrial scale biofuel production in Africa will not and cannot develop without improved road infrastructure.

Appropriate location of processing plants is critical to the success of any venture including biofuels and the availability of fairly well developed infrastructure, which can transport feedstocks and products efficiently and cost effectively is another major factor. A suitable location also must have reliable and efficient communication, commercial and banking network. In order to attract trained and skilled manpower the site must have social infrastructure including schools, medical and recreational facilities etc. Accessibility and proximity to markets is another important criterion.

There are contrasting views about whether biofuel development in Africa could be a significant contributor to the infrastructure development in the region. However, partnerships between governments, private sector and development assistance agencies could accelerate the current process.

Rural development and livelihoods

One of the added benefits of biofuel production in developing countries is the potential contribution to rural development, a few examples follow. Mathews (2008) illustrated the potential impact of biofuels on the development of Zambia. Setting up a 200 megaliter (ML) bio-refinery producing ethanol from sugarcane grown on 50000 ha of land, and farmed by peasants at 10 ha per family resulted in annual family income of $10,250 USD in a country where estimated per capita GDP is $921 USD (Bureau of African Affairs 2008). Brazil sees biofuels production as a way to promote rural industry and to curb the flight from rural areas to mega-cities. Biodiesel produced from castor beans in Brazil's arid northeast hinterland, for example, is promoted not just for the biodiesel but also for the fact that it creates thousands of jobs in this otherwise impoverished region (Phillips and Gow 2005). In India the production of biodiesel from jatropha is also explicitly promoted as a rural industry capable of generating village-based enterprises (Singh 2006). AGAMA Energy (2003) concluded that bioenergy offers a quantifiable potential for creating and sustaining new and decentralized employment in South Africa and that the government could stimulate massive employment gains fairly quickly and easily in the biofuels sector. These could show good returns on limited government investment even in the very short term.

Biofuel programs can be small-, medium- and large-scale with production for local, national or export. These different systems have varied impacts both positive and negative on rural populations and environments (Woods 2007; Milder et al. 2008) and require appropriate institutions and planning to assure positive outcomes. Various development options for biofuel programs are presented here along with some illustrative case studies.

box 15.4

Small-scale village initiatives

India

The electrification of three villages in the State of Chattisgarh using diesel generators operating on straight vegetable oil derived from jatropha has been initiated through collaboration with Winrock International India with the objective of demonstrating the technical and financial viability. Ranidhera village, 15 km from the nearest grid access point, has 110 households with 600 residents. The community manages and operates the facilities including tariff setting and collection of electricity fees. A 10 member Village Energy Committee (VEC) operates the power plant. Twenty-five thousand Jatropha saplings were planted on farm boundaries, road sides and waste land - no productive farm land was used. The power plant, consisting of three 3.5 kW gensets, oil expeller, filter press and boiler, was installed on 9 April 2007 has been in continuous operation since without any technical failures. The electricity is generated between 6-9.30 pm and distributed through a mini-grid that powers 30 streetlights, 107 homestead light points and 65 sockets (for entertainment). Revenue generated from electricity sales is used to pay the salary of the operators, cover maintenance expenses and the surplus is for investment in an expanded energy supply system.

The villagers of Ranidhera highly appreciate the electricity services provided to their households enabling them to work and study in the evening hours. Furthermore, the street lights facilitate safe walking through the village by night and TV/radio is used for entertainment and outreach.

Mali

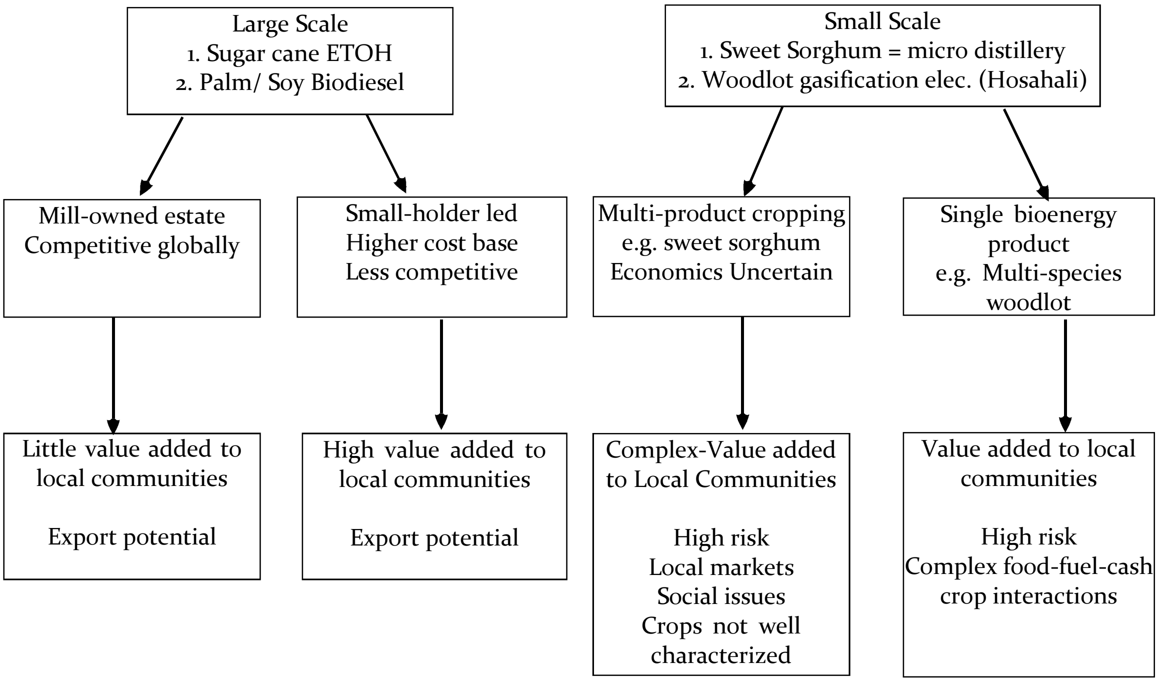
Mali has several small scale jatropha projects. In 1987, the Special Energy Programme funded by GTZ began activities using Jatropha as a substitute for diesel (Henning 2007). Ten years into the project, 10,000 km of Jatropha hedge had the potential to produce 2000 tonnes of oil. The Mali-Folkecenter (MFC) took over the activities in 2000, developing “energy service centres” involving 20-hectare jatropha plantations that provide energy to local communities for activities such as millet grinding and battery charging. In partnership with, UNDP and the Global Village Energy Partnership, MFC launched a 15 year, 1,000 hectare jatropha project that will provide power to more than 10,000 local residents through the Multifunctional Energy Platforms (MFPs). These comprise 10 H.P diesel engines capable of driving up to a dozen ancillary modules (e.g. grain mill, de-huller, shea butter press, electric alternator).

Another example is from Mali Biocarburant, a Dutch-backed start-up company that is aims to create an economically-viable biodiesel company based on collections of jatropha seeds from thousands of smallholder farmers (Dominique 2007). The difference between this and similar projects is the lack of any central plantation. Instead, they will rely entirely upon existing jatropha trees, mainly planted as fencing, to begin production in the first half of 2008. The goal is to produce five million liters per year within five years, which will require the annual collection and processing of approximately 20 billion jatropha seeds.

Biofuel development options (Woods 2007) that are likely to affect rural development in different ways are presented in Figure 15.2. One is the two pronged large-scale production systems where in one prong, feedstock is grown in large mono-culture plantations so as to maximize profits for large scale farmers, processors and energy companies. Livelihood benefits from this system are more relevant at national level and, in fact, may marginalize local communities by relocating community lands and protected areas to feedstock production. Such an example is shown in Mozambique that is being targeted by sugarcane bioenergy production investors (e.g. Agencia de Informacao de Mozambique 2007) because it has the largest availability of land suitable for sugarcane, but also because the land belongs to the Government and this entity is easier to negotiate with. In the second prong of large scale production, feedstocks are grown on smaller farms and then sold to commercial processors. The farmers can best benefit from this system by organizing themselves into cooperatives and have a strong negotiating power for fair marketing. This system works best when farmers are linked together with relatively large nucleus farms (see Tanzania case study below) without which insecure delivery of goods becomes a challenge.

The second option is small scale production systems, where feedstocks are produced on small plots, usually integrated with food crop production, but can also be grown singly e.g. in woodlots. Such systems are suitable in countries with multiple small scale land owners, tenants under tiers of traditional authority and variable land

Figure 15.2 Different scale models for bio-energy production in developing countries (Woods, 2006)



reform aspirations. Biodiesel is most conducive in this system, and is processed and marketed locally for local fuel consumption. Feedstock producers are, therefore, likely to receive a large share of revenue from this system. Other offshoot benefits are those associated with the increase in crop diversity and integration such as restoration of unproductive lands, enhanced soil fertility and protection against pests and diseases. The small scale systems are often beset with a large range of technical and non-technical issues increasing the risks as outlined in Figure 15.2.

Large and small scale biofuel production: lessons and opportunities

The case studies presented (see boxes 15.3, 15.4, and 15.5) provide scenarios of biofuels development that show the current state of play and suggest the potential for the future. In Brazil, development has occurred mainly in ethanol production, having been facilitated by strong biofuels policies being in place and adjusted as the situation warranted, as shown in the example of Brazil. Brazil also exports biofuels to several countries around the world. The country is now however dealing with the social and environmental issues that have risen from their policies and attempting to address them through additional policies. Other developing countries, where experience with biofuels is new and at smaller scales, mainly targeting biodiesel production to address local markets as an engine for social development have lessons to learn from Brazil; whereas Brazil can also learn many of the social and local economic development issues of these more recent and local projects. The Brazilian experience shows that developing a biofuels industry is long term, demanding a sustained and adaptive policy commitment that is best based on identification and analysis of the opportunities, risks and trade-offs, and adjusting policies as required.

Conclusions and research needs

The recent experiences of high fuel prices and the mismatch between global demand and supply present optimism about the potential of biofuels. Export opportunities (feedstock and finished products) for many of the developing countries with comparative advantages of available land for low-cost feedstock production now appear real. However, some areas will struggle with addressing biophysical and infrastructure hurdles mentioned in this chapter (e.g. lack of roads, low soil fertility, access to water etc.) to make the ventures profitable. It is also important to emphasize that the success of biofuel export from developing countries to developed countries will depend on the future policies of countries such as the US and EU, which subsidize domestic, but inefficient, biofuel agro-industries resulting in trade barriers. Brazil currently has difficulties competing against European and American biofuels because these trade barriers. As a consequence, developing countries have to produce biofuel with a very low price, and often at the expense of the environment.

Countries must follow a decision process in order to fit the biofuels industry within their development strategies and available resources (physical, monetary and institutional). First, countries must define their overall objectives, as well as the policies needed to support those goals, which may be guided by the potential benefits identified. This should be followed by choice of feed-stock; the main target for Brazil has been sugarcane for bio-ethanol which requires large areas of land and available water, but other developing countries may

box 15.5

Hybrid initiatives

Tanzania (Kilombero Sugar Company (KSC) Outgrower Scheme)

This case study provides an example of a hybrid between large-scale and small-scale production of sugarcane, based around a sugar mill in Kilombero Valley, Tanzania (Illovo, 2005). The Kilombero Sugar Company (KSC) and mill was established in 1960 and from the beginning had a component of feedstock supply coming from out-growers. By 1976, the out-growers supply of cane had grown to 103 000 tonnes but under continued government ownership and cash flow problems, sugar production declined to 27, 000 t by 1997. Outgrowers were supplying less than 100,000 t of cane and their incomes had declined substantially. It was obvious that the mill and associated sugarcane production was in terminal decline.

In 1998, Illovo, a multi-national sugar company, won a bid to own 55% of the sugar mills and estates, ED&F Man Holdings Ltd purchased 20% and the government retained 25% ownership in order to guarantee the continued role of the out-growers who organized themselves into two cooperatives. With the renewed investment from the private sector, sugar production grew to 130 000 tonnes in 2004 with the out-growers providing over 53,000 t cane.

The re-investment in the sugar mill and size of the parent companies has meant that, with reasonable supply contracts, the out-growers have been able to gain credit from the local banks and have the confidence to invest in their own production capabilities. The two cooperatives are now also investing in schools, roads, hospitals etc having partly taken over these responsibilities from KSC. KSC itself provides: housing for its 6000 employees, 43 teachers and 56 police personnel; a health clinic and hospital for 10 000 patients per year; buildings and maintenance for 6 primary schools and four daycare centers and potable water supplies; and has formed a Kilombero Community Trust.

Whilst KSC has slightly higher sugarcane production on its own estate and would provide more returns to shareholders if it produced all the sugarcane needed to supply the mill, the value gained by the local communities through the out-grower scheme is greater because a share of the profits is retained locally and the local communities have benefited. This case shows that small-scale out-grower schemes can be a successful way of capturing foreign investment to significantly increase the income and productivity of rural communities in developing countries when conditions are favorable. The mill already produces surplus electricity which it sells to the national grid and ethanol could be produced from the residual C-molasses and used as transport fuel, further increasing the revenue potential for the out-growers.

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target biodiesel production from a range of crops that could be grown cooperatively by smallholder farmers.

The choice of feedstock must consider and assure food security, environmental protection, social equity and national/rural development. This choice must be informed by market options; local, national, international or a combination of any of these. When a decision is made that the biofuel industry is appropriate, implementation mechanisms must be put in place to address investments in inter-sectoral research and technology access, provision of incentives at all value-chain stages and policy coherence over time.

Further research is need in the following areas:

Feedstock – There is a diversity of food and non-food crops that have potential for biofuel feedstock in tropical developing countries. There is need for a systematic approach to screen species and management practices. Brazil has conducted considerable research into sugarcane and its agronomic requirements, including water needs, and there is potential for south-south expertise and knowledge transfer. Similar research should be conducted on other feedstock crops; there is need to verify the performance and fuel production potential of various accessions of some of the existing and less known local feedstock plants. Research networks are best suited to establish how these successions would perform when moved to other locations with different environment (soil, climate) and management practices.

Land availability and competition for food crops - Rough calculation indicate apparent land availability differs from region to region. There is need for detailed regional and national assessments of the amount of land available, the quality of that land for producing biofuels, the inputs and infrastructure needs, and foremost the potential conflict for and displacement of land for food production and the potential to increase food insecurity.

Environmental impacts – The viability of biofuel production in developing countries has to include environmental impact assessments and considerations in the planning and implementation stages. As indicated by some case studies, there is need for holistic assessments to cover the varied local, regional, and global impacts and that these assessments cover the entire life cycle of the biofuel production.

Social considerations and rural development - Developing countries are well know for high poverty levels but also income inequalities. Biofuel programs may bring rural development but also could be a means of companies and few individuals to concentrate wealth and political power. Policy research is needed to identify approaches and policy tools that would benefit the rural poor.

Use of international conventions to promote environmental and socially sustainable biofuel programs in developing countries – Many of the current international agreements in climate change, biodiversity and desertification provide opportunities to benefit rural communities. To date however few rural, poor communities have benefited because of lack of evidence that they can be implemented as such and reportedly high transactions costs. Some key pilot studies must be developed to quantify the local benefits that might be realized through such programs but also the implementation and monitoring costs associated with them. Only then will there be large-scale application of these international conventions for the benefit of poor, rural populations.

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