Food production needs fuel too: perspectives on the impact of biofuels in southern Africa

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Southern Africa is faced with the complex challenge of achieving sustainable economic development and food and energy security while protecting the environment. The region is currently experiencing an energy crisis, a result in part because of global increases in crude oil prices and limited generating capacity in some countries. We examined the potential of biofuels to address the aforesaid problems and their role in the agroecological and socioeconomic systems in the region, highlighting the challenges to be overcome before biofuels can become an integral part of the regional socioeconomic dynamics. Major hurdles to biofuels establishment include relatively poor awareness of the potential and opportunities presented by biofuels, technology challenges, food insecurity vulnerability associated with the use of grains such as maize as feedstocks, potential conflict in resource allocation between food and fuel crops, and good governance and its impact on stability of food supply. Resource allocation and the balance between the need for food security and fuel is discussed in the context of selection of a crop matrix that does not compromise food security or limit development of the biofuels sector. While the use of maize for ethanol might enhance producer prices, it may contribute to high food inflation and political unrest. Sweet sorghum on the other hand, presents an opportunity to provide food and bioethanol without compromising food security. Biofuels have great potential in southern Africa, but there is a need to establish and nurture the development of capacity, in the value chain from production to consumption, to realise the benefits of biofuels in the region.

Introduction

The developing world faces huge challenges in achieving basic food security and economic development in the face of soaring crude oil prices. The recent food riots in more than 30 countries,[1] a result of scarcity and food inflation, have been directly associated with the price of oil and the surge in the utilisation of grain as a source of bioenergy. Between 1997 and 2008 the price of crude oil increased from $27 to over $100 per barrel, and the recent boom in the Asian economies of China and India, with a population of over 2.5 billion between them, is exacerbating the situation—both of these countries are heavily dependent on oil, mostly due to the rapid advancement of the transportation sector in these economies resulting in higher income elasticity of demand.[2] While previous oil shocks in recent history were caused partly by sudden interruptions in exports from the Middle East, the recent crises were a combination of several complex factors including a steady increase in demand for oil, especially in rapidly growing economies like China and India. With the volatile political situation in the Middle East, which accounts for 56% of the global oil reserves,[3] coupled with oil conflicts in Nigeria, natural disasters like hurricanes and the growing demand from Asia, an upward trend in crude oil prices can be expected for the foreseeable future. The crude oil prices have been temporarily tempered by the global economic slump, but the long-term trend is expected to be upward. However, the turbulent oil market, and knock-on effect on food inflation, and the improved awareness of climate change have given rise to an unexpected political will and financial commitment towards alternative environmentally-friendly fuels, such as biofuels.

Biofuels are gaseous, liquid or solid fuels rendered from raw biological materials (plants, sewage, dry matter, cane sugar or wood pulp). Those developed by 'conventional technology' are commonly known as first generation biofuels and include vegetable oil, bioethanol, biodiesel and butanol, among others (Table 1). Biofuels that are made from cellulosic biomass feedstocks, using advanced technical processes, are called second generation biofuels and include biohydrogen and bio-dimethyl-ether (bio-DME). Although some of the fuels are as old as human civilisation, the past decade has seen unprecedented investment in new technologies aimed at driving old and new fuels into the mainstream economy. In this review the term biofuel refers to the liquid biofuel unless otherwise specified; wood and charcoal would be referred to explicitly. Global interest in biofuels continues to soar as a result of the recent crises and increasing awareness of the many challenges of relying on petroleum, particularly for transport fuels, but also as a source of polymers. While major milestones have been made in transport fuel production from fermentation technologies that utilise sugarcane and corn in Brazil and the U.S.A., respectively, in other parts of the world commercialisation of bio-based materials is developing at a very slow pace. We discuss progress in the development of biofuels, as well as the associated environmental and socioeconomic issues from a southern African regional perspective. Southern Africa, and South Africa in particular, is suffering from the worst energy crisis in its history owing to the escalating global oil prices, poor planning on infrastructure development and production constraints. A clearer picture of the niche of biofuels can thus only be extrapolated from the overall energy demand and supply dynamics of the subcontinent. Some obvious differences in this regard prohibit a 'one-blanket-fits-all' inference as far as energy is concerned, and such differences will be highlighted.

Energy context in southern Africa

The population of the African continent is expected to reach 1.3 billion by 2020 and 17% of these people will reside in southern Africa.[4] Agriculture and mining sectors contribute the largest share to the African economy, employing more than two thirds of the working class. Overall, 45–50% of Africans live below the poverty datum line,[4] which highlights the enormity of the challenges for sustainable development. In addition to the heterogeneity in food security, public health, industrialisation, political and socioeconomy, the continent has a complex regional energy usage and balance that makes it difficult to predict the impact of new technologies such as biofuels.

Africa's total energy supply is growing at an extremely slow pace; its global share of total primary energy supply has only increased from 3.5% to 5.2% between 1973 and 2003, despite an annual increase in population of about 3% for several years, indicating a reduction in energy access on a per capita basis.[5] It is estimated that about 5.6%, 8% and 9.5%, of the world's proven global economic recoverable reserves of coal, natural gas and oil respectively, are in Africa.[6] Africa produces 7% of the world's commercial energy, but consumes only 3% and exports more than half of its production.[7] Figure 1 shows the percentage energy demand across the continent. More than half a billion people in Africa rely on solid

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Table 1. Feedstocks for various biofuels and their fit within the southern African context.

Biofuel	Feedstock	Fit with agroecosystems in southern Africa	Socioeconomic potential	Concerns
Bioethanol	Sugarcane	Minimum rainfall of 600 mm Widely grown in the region already, possibilities for expansion	Technology for production established in the region Ethanol blending already in place Bagasse usable as fuel /cogeneration or cellulosic feedstock	High water requirement can be a challenge
	Sweet sorghum	Low water requirement Drought tolerant and better adapted to marginal growing conditions Fits with both commercial and small-holder agriculture	Fits with the sugarcane ethanol production technology Does not compromise food security for the poor Dual nature as source of grain and sugar uniquely attractive Some varieties have extremely high sugar content	Varieties required for year-round production
	Maize grain	Well adapted to the region, grown in commercial and subsistence sectors Susceptible to droughts that are frequent in the region	Technology for maize ethanol well established in other parts of the world	Conflict with food security, which is paramount in southern Africa Rising grain prices may negatively affect viability
	Cassava	Already grown in the region, potential for expansion Tolerant to drought, acidity and salinity, thus less competition for prime agricultural land Potentially high yielding	High yielding, socio-economically attractive Important for food security and other uses	Need for a programme for research Need for a strong programme to promote crops with the farmers
	Sugar beet	Subtropical varieties now available Can be grown in relatively dry areas, needs less water than sugarcane Fast-growing, farmers can put in two seasons per year	Similar sugar output to sugarcane	Farmers have yet to learn how to grow this crop Varietal trials ongoing in South Africa
	Sweet potato	Crop already grown at small scale in most of southern Africa Well adapted to the region	40–50% more starch than maize Productivity 3–4 times higher than maize	Large potential that is yet to be realised through improved varieties and promotion of crop
Biodiesel	Soybean	Well adapted to many countries in southern Africa Can be grown with minimal or no nitrogen input, a major cost of production	High-value by-products, such as soy cake, is an additional incentive Relatively low (2.7 t ha^{-1}) yield per unit area, poor producer of biomass	So far crop has been successful in the commercial sector
	Jatropha	Low rainfall requirement and drought tolerance make it broadly adaptable Grows on marginal land, does not compete with agricultural crops Can be used for land reclamation, and to combat desertification and deforestation	High oil content enhances economic viability Simple expression technology 5–40 years economically-productive life By-products potentially stimulate rural industry	Invasive nature causes environmental concerns
	Sunflower		Low yield (1.5 t ha^{-1}) yield is still significantly lower than soybean and corn High value oil better suited for domestic purposes	Better value for table oil
Cellulosic bioethanol	Wood	Available as by-products of the forestry industry	Region has reasonably organised forestry industry that can utilise by-products	Not all countries have a viable forestry industry
	Cereal stover	Available as waste products of cereal	Stover currently utilised as livestock feed in the dry season	Might compete with livestock feed
	Municipal waste	Suitable for large urban centres	Potential in South Africa, but garbage disposal advanced to encourage recycling and separation of cellulosic material	

biomass (fire wood, agricultural residues, animal waste) to meet basic energy needs for cooking, heating and lighting.[8,9] These fuels are generally labour intensive, inefficient, polluting and destructive to the environment through deforestation and desertification. For most countries, commercial energy sources are generally under-developed; the infrastructure, such as pipelines and power grids, to deliver commercial energy to customers', especially in rural areas, is poorly developed. This poor development negatively affects service delivery, in particular education and health services, to the bulk of the region's population. Unfortunately, the above scenario accurately describes the current status of most southern African countries, excluding South Africa (Fig. 1).

Southern Africa has a unique pattern of energy sources and usage owing to the dominant influence of South Africa, which has the lion's share of energy resources and consumes the largest fraction of energy produced in the region. As the economic powerhouse of the region, it influences patterns in fuel production, consumption, carbon emissions and most importantly energy policy. As a consequence of the current rapid economic growth, coupled with a coal-dependent industry for power generation, and to an extent synthetic liquid fuels made from coal, South Africa is among the largest emitters of greenhouse gas in Africa and one of the most carbon emission-intensive countries in the world.[10] This leaves the country very economically vulnerable to the possible climate change response measures currently being implemented by developed countries.

For the past five years, South Africa has had rolling electricity blackouts as a result of a peak generation capacity that cannot cope with the rapid economic develop-

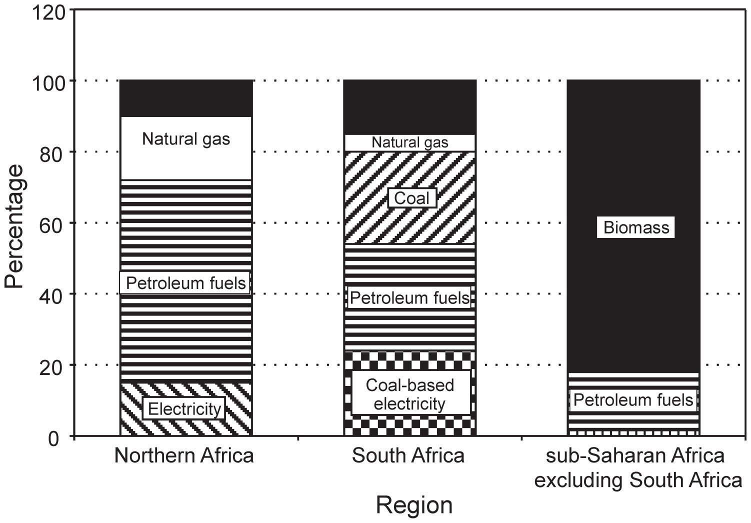

Fig. 1. Percentage energy demand in Africa by region, 2001.[6]

ment and the related increase in demand. Energy security through diversification of supply in South Africa is one of the key goals of the Government of South Africa's 2003 White Paper On Renewable Energy Policy,[11,12] since a major portion of the nation's energy expenditure is via dollar-denominated imported fuels that impose a heavy burden on the economy.[11] Unfortunately, the situation is even worse in other countries from the region. Clearly the need for energy supply diversification for South Africa and its neighbours cannot be overemphasised.

A modern and diversified energy sector for southern Africa is not only a prerequisite for economic growth but also a human rights issue as it affects health, food security and stability, as evidenced by the food riots elsewhere.

With that background this paper aims to assess the potential of and the niche for biofuels in southern Africa as well as to critically analyse the strategies that could be adopted if this promising technology is to succeed in our region. Research into second generation fuels is still in the early stages but their potential within South Africa is well articulated by Lynd *et al.*[13] and thus will not be addressed here. Instead, we focus on bioethanol and biodiesel, and analyse their potential impact in the regional context.

Bioethanol

Ethanol is the most common biofuel worldwide with more than 50 billion litres (both fuel and non-fuel) produced in 2006.[14] The U.S.A. was the leading producer of bioethanol, followed by Brazil; both countries accounted for over 70% of the world production while China and India occupied the third and fourth positions, respectively, during the same year.[14] Ethanol production in Africa accounted for just over 1% of the world production, over two-thirds of which is produced in South Africa (Table 2). Table 3 shows the various countries with notable bioethanol initiatives and the various drivers for bioethanol in each country. The process of making ethanol generates a series of valuable coproducts including corn oil, protein feed, gluten meal, germ, refined starches, corn sweeteners and commercial carbon dioxide. The value of the final products is roughly double that of the raw corn[15] and contributes to the economic viability of some biofuels.

Bioethanol can be produced from three types of feedstock: a) from starch contained in different food crops, such as corn, wheat, cassava and potato; b) from stalks of sugar-accumulating crops, such as sugarcane and sweet sorghum; and c) from cellulosic materials from virtually any plant or plant parts, such as wood and crop residues (see Table 1). Cellulose and hemicellose are the main components of plant cell walls and constitute the most abundant sources of carbohydrate on earth. Even though the technology for converting starch and sugars to ethanol has been well developed over thousands of years,[11] the production of ethanol from cellulosic material has been a matter of intensive investigation. Ethanol has a high octane rating and the high heat of vaporisation makes it more efficient as a pure fuel than gasoline. Because ethanol is less volatile than gasoline[16] and has a low photochemical reactivity in the atmosphere, smog formation from evaporative emissions of pure ethanol could be less than for gasoline. Ethanol is usually blended with a fossil fuel, for example, the U.S.A. has two major blends: E10 (10% ethanol and 90% gasoline) and E85 (85% ethanol and 15% gasoline); a number of other countries have mandatory or proposed biofuel blending policies.[14,17] The higher blends require the modification of engines and therefore many car manufacturers, particularly in countries like Brazil, are producing flexible-fuel vehicles, which can safely run either on 100% bioethanol or on any combination of bioethanol and gasoline blend. As clearly outlined by Gnansounou and colleagues,[18] ethanol has excellent fuel properties for spark ignition internal combustion engines.

Table 2. The world's largest ethanol producers (all grades), as a percentage of the global production in 2006. World total production of ethanol in 2006 was estimated at 51 billion litres.[14]

Country	Percentage of global production
U.S.A.	39.1
Brazil	33.3
China	7.5
India	3.7
France	1.9
Germany	1.5
Russia	1.3
Spain	0.9
South Africa	0.8
Africa (excl. South Africa)	1.2
Others	8.8

Biodiesel

Biodiesel is produced from vegetable oils by converting the triglyceride oils to methyl (or ethyl) esters in a transesterification process that yields glycerine as one of the byproducts.[19] The glycerine can be further purified and sold to the pharmaceutical and cosmetic industries. However, this market is very limited and other uses will have to be found to accommodate large volumes of glycerine production. Biodiesel can be used in existing diesel engines without need for modification, and can be blended at any ratio with fossil fuel. It is nearly 10% oxygen by weight,[20] and is a non-toxic fuel that can be produced from a variety of renewable resources, including plant oils (soyabeans, rapeseed oil, palm oil) and animal fat, and can be used in its pure form or blended. Compared with fossil diesel, biodiesel has significantly reduced emissions of particulates: emissions of sulphur oxides and sulfates are almost negligible. Carbon monoxide emission is reduced by 48%, particulate matter responsible for nasty medical conditions by 47%, long-chain hydrocarbons that cause localised formation of smog and ozone are reduced by 67%, while carbon dioxide goes down by up to 40% for 5–100% blending.[21] Moreover, biodiesel biodegrades four times faster than petrodiesel, and at about the same rate as dextrose. All these attributes make it especially environmentally friendly. Moreover, biodiesel has a higher net energy balance, making it a more attractive choice for the developing world.

Table 3. Biofuel efforts and initiatives in southern Africa.

Country	Initiatives and experiences
Zimbabwe	One of the success stories in southern Africa when operational
	Blending at Triangle sugar plant (40 million litres per annum), 1980–1992
	Blending 13–18%
	Drought in 1992 reduced feedstocks, and resuscitation attempts to date have failed
	Economic and political factors favour export
	Success stories in public–private partnership, local material (60%), clear pricing policy, well-planned implementation strategy, food fuel dilemma not critical (sugarcane export crop)
	Difficulties with sanctions, security of supply, foreign currency and land reform policy
	Ethanol processing piggy-backed on sugar-milling plants
	In 2007 commissioned biodiesel processing plant to use jatropha, cotton seed, sunflower and soyabeans
Malawi	Blending at 15–20% since 1982
	Dwangwa plant produces15–20 million litres per annum and the new plant at Nchalo has a capacity of 12 million litres per annum (2004), both sugar factories
	Plant costs are $8 million and savings are $32 million (1982–1990)
	Success factors include steady feedstock availability, irrigation water (Lake Malawi), clear and consistent policies, incentives and pricing
Kenya	Madhvani project failed because of costly design
	Muhoroni plant annexed to sugar mill has a capacity of 60 kl per day, at a cost of $15 million
	Blending at 10%
	Project is continuously making a loss because of uncompetitive pricing, poor management, resistance from oil companies and loan-servicing burden
	Blending discontinued in 1993 but ethanol currently being exported
Zambia	About 16.5 million ha arable land but only 14% cultivated
	Agriculture employs 67% of population and sustains 50% of livelihoods
	Imports all its fuel requirements—supply and price uncertainty
	Allocated $150 000 for jatropha trials in 2007 and researching sweet sorghum to complement sugarcane for ethanol production
	Biofuel standards legislation enacted, energy policy changed to accommodate biofuels, biofuels association of Zambia (BAZ) formed
	Targeting 5% and 10% blending for ethanol and diesel, respectively, by 2011
Swaziland	Jatropha cultivation approved (2007)
South Africa	New proposal for ethanol from maize in 2007
	White paper on renewable energy (December 2003) proposed 50% of total energy to be renewable by 2013, and biofuel to constitute 20–50% of this
	Biofuel industrial strategy proposed 2% market penetration (40 million litres per annum) of biofuels by 2013
	Feedstocks—sugarcane and sugar beet for bioethanol, and sunflower, canola and soybeans for biodiesel
	Fuel levy exemption for biofuels to increase from 40% to 50% (2008/2009)
	100% fuel tax exemption (R1.21 per litre for ethanol and R0.53 per litre for biodiesel)
Mozambique	Planned 5–10% blending across the country (nine initiatives) with copra oil, cotton, sunflower, jatropha as feedstocks
	Legislation enacted on tax incentives, custom duties exemption and special economic zones
	Public–private partnership initiative with two bioethanol plants ($28 million producing 33 000 m^3) and two biodiesel plants ($30.2 million producing 40 000 m^3)

Net energy balance of biofuel feedstocks

Net energy balance (NEB) analysis is the most common measure of the economic and environmental impact of biofuels vis-à-vis fossil fuels. It equates to the relationship between energy input and energy output throughout the energy crop production to biofuel production cycle.[22] A fuel with a NEB value of greater than one means there is more energy output than energy used to produce it, and thus is a better fuel. In order to reduce carbon emissions into the atmosphere, biofuel crops should yield more energy than consumed to produce and process them. NEB depends on factors such as mechanisation, pesticide and fertiliser use,[23] and mode and distance of transport, among others. Therefore different crops and farming systems require different energy inputs and produce different yields, resulting in differences in NEB. For example, a reduction in farm inputs like fertilisers and chemical pesticides may increase energy balance. Further improvements in crop yield and future generation biofuels, like lignocellulosic feedstock from short cycle woody plants, grasses and crop residues, have been shown to yield better net energy and environmental benefits than the current food crop-based biofuel feedstocks.[22–24] With limited data on NEB, especially for developing countries, the NEB calculations are usually approximations from Europe or the U.S.A. and these are based on certain parameters of feedstock production and processing and other assumptions. Table 4 shows the approximated NEB for the major biofuels and shall be used as a reference for further discussions. It is interesting to note that sugarcane has the highest NEB and so does sweet sorghum (Table 4). This suggests that there is a big gain in NEB, expected from an improvement genetically or agronomically, for these tropical high energy-efficient C_4 plants. Biodiesel from soybeans has more than three times the NEB of corn-based bioethanol, even under the heavily mechanised U.S.A. farming system.[25] This could be due to the reduced nitrogen fertiliser input and processing requirement of soybean.[25]

In summary, one can predict substantial increases in the NEB of biofuels owing to: a) genetic improvements of the existing crops/feedstocks; b) improved agronomic practices, to lower inputs without compromising yield; c) improved conversion technologies; d) discovery of new feedstocks (both crop and cellulosic); and e) better business models, since the biofuel industry has its own unique challenges that call for business solutions.

Table 4. Net energy balance (NEB) of fossil fuel and major biofuel feedstocks.

Feedstock	NEB (energy output/fossil energy input)
Petrol	0.8
Wheat (Canada)	1.2
Maize (U.S.A.)[25]	1.3–1.8
Sugar beet (EU)	1.9
Cellulosic[27]	4.4 to 6.61*
Soybeans (biodiesel U.S.A. mechanised)[28]	3.2
Switch grass[26]	4.4
Sweet sorghum[23]	8
Sugarcane[29]	8.3

*Net energy return on investment (not NEB).

Socioeconomic drivers of biofuels

In order to have a clear understanding of the impact biofuels may have in southern Africa we dissected the major drivers of the technology, globally and regionally. Broadly, geopolitical and economic drivers have played a major role in the development of biofuels. Geopolitical factors include supply security and post-Kyoto emissions reductions, and economic drivers are the prices of fossil fuels and advances in biofuels technology. The need to alleviate over-reliance on the volatile Middle East oil supply is common to many regions of the world. Climate change and the role that the burning of fossil fuels has played in this phenomenon have driven the agenda in biofuels development in the developed world. In the European Union (EU), there is an overall acceptance of the need to reduce pollution by working gradually towards environmentally-friendly fuel alternatives and biofuels are viable candidates. The EU has put in place a policy package to reduce greenhouse gas emission by 20% in 2020 and to reduce dependency on fossil fuels. In the U.S.A., major gains in carbon emissions in the range of 72% and 7% per kilometer have been realised in the U.S.A. on their E85 and E10 blend fuels, respectively.[25,30]

The major drivers of biofuels in the U.S.A. are the high prices of liquid fuels, the transfer of billions of dollars out of the U.S.A. economy to purchase fuel abroad, reliance on unreliable (and sometimes antagonistic) overseas suppliers, and the perceived need to reduce the usage of fossil fuels, which has led to widespread support for producing liquid fuels from renewable agriculture-based feedstock.[31] There is the need for a reduction or end to the overdependence on fossil fuel from the unstable Middle East whose conflicts have pushed fuel prices to record highs.[32] Domestic economic aspects such as value addition to grains to support family farms and unemployment figures, both of which are exacerbated by the chronic global oversupply of most agricultural commodities, have encouraged diversion of agricultural produce to the production of bioenergy with a view to stabilise commodity prices. For example, the diversion of part of the maize crop to ethanol production in the U.S.A. helps maintain the maize price, reducing the need for price compensation and export subsidies. Under the current market circumstances, crude oil and gasoline prices have become the main driver for ethanol supply expansion.[31] Diversion of maize and other grains to ethanol production has, in part, led to the current grain crises that have led to food riots across the globe. Other drivers of biofuels development include tax credits, grants and loans, feedstock costs, energy input costs, coproduct prices and advances in biofuels technology.[32]

The demand for affordable energy is a major issue in developing countries. In southern African countries, like other developing countries, a key motivation in the development of biofuels is the possibility of diversifying energy resources and displacing large oil import bills with spending on locally-produced biofuels. Most of the countries, being land-locked, have to contend with paying high fuel prices on the world market as well as the cost of transporting the fuel over long distances inland. The associated opportunities for rural development, which benefits from a dynamic bioenergy sector, are also an important factor. While the need for reduction in emissions from fossil fuels is a major global driver, pollution from industry in southern Africa is not a major problem except for South Africa, which has a highly-developed industrial sector with huge energy demands, the bulk of which are met via electricity generation from coal. A key discussion in the Bali Road Map, a U.N. conference on climate change in Bali-Indonesia in 2007, focused on the development of a new protocol to succeed Kyoto, especially on how developing countries can curb emissions. Industry, for example, has for a long time relied on road transport for regional and cross-border transport and very limited rail transport inland, resulting in high transportation costs and related emissions. Being signatories to the Kyoto protocol, it makes political sense for the SADC region to be planning future development initiatives to be powered in part by environmentally-friendly energy sources. Having said that, unemployment figures are reaching alarming levels, for example 36–42% in South Africa (2007 estimate) and 80% in Zimbabwe (2005 estimate),[33] making local job creation and generation of wealth, especially with labour intensive feedstocks from rural areas, major drivers for biofuels. This is confirmed by the South African Biofuels Association (SABA),[34] who describe the creation of sustainable income-earning opportunities in marginalised areas as the primary motivation behind biofuel production in South Africa. Furthermore, a biofuel industry targeting the emerging farmers may create an additional market with stabilising influence on prices and income for such projects.[34]

Benefits from biofuels

The most obvious benefit of biofuels would be the possibility of a locally-produced fuel to supplement fossil fuels and the subsequent reduction in oil import bills. Biofuels can also meet the energy demands of rural communities, circumventing the problems of poorly-developed grid networks, and this in turn will result in ripple beneficial effects such as electricity supply to rural schools and health facilities, thus stimulating economic growth. Long-term energy security from renewable sources is a key benefit, since energy supply is a key driver of economic growth. Biofuels, such as vegetable oils and biodiesel, can contribute to small-scale power production in rural areas and be competitive in displacing more expensive fossil fuels. Ensuring that the economic and social benefits of biofuels reach small-scale producers, however, will require ongoing efforts to reduce costs and enhance efficiencies of small-scale generation systems.

As biofuel industries grow, significant economic opportunities can emerge for small-scale farmers and entrepreneurs as the production, transport and processing of crops often takes place in rural areas. Rural communities can also derive income from the processing of biofuels by-products, such as soap production, fertilisers and cattle cakes. Agricultural crops for biofuels can offer new income streams for farmers. Non-edible crops can be grown and harvested for biofuel applications and several biofuels feedstocks can be planted and grown on arable and marginal lands that are not under cultivation. Small-scale biofuel production and use implies no net increase in atmospheric carbon and could contribute to a reduction of greenhouse gas emissions if it is produced and used on a larger scale, displacing fossil fuels.

Hurdles to biofuels production in southern Africa

Despite the potential of biofuels to address both fuel security and rural development, there are several hurdles that are yet to be overcome. In general, there is a low-level awareness of the opportunities and potential benefits of biofuels by stakeholders in the various sectors of the economy, from the various government departments and the private sector, and to the farmers. This is exacerbated in most of the countries by the absence of policy frameworks and instruments to facilitate realisation of these opportunities. This hurdle could potentially be overcome by governments putting in place policies to support the development of biofuels, from feedstock supply, which requires highly organised agriculture; acceptability by the motor industry, which necessitates legal and regulatory frameworks; and financing required at all levels.

Technology limitations are a key hurdle to biofuels establishment. Biofuel production and consumption (blending) technologies are new to some parts of the subregion, and introduction and establishment of new technologies is a long-term effort and as such immediate impact should not be expected. Investment in appropriate research and development support in all aspects of the technology is essential to the success of biofuels. Capital investment is also required to establish some of the technology, and this requires financial commitment from both government and the private sector. While such commitment is apparent in some countries such as South Africa, the other regional economies appear to be simply too small to make meaningful investment, emphasising the need for regional cooperation.

Availability of appropriate biofuel feedstocks in adequate amounts, and in steady supply throughout the year, is a major challenge. Agricultural support services will thus need to be enhanced to bolster the production of feedstocks (new and established). The crop mix for biofuel requires careful selection. In most of the countries in southern Africa, there are currently no fuel crops specifically for biofuels production; the crops that could be used as feedstocks are currently grown for human and animal consumption, hence the need to scale up production of existing crops and to introduce new specialised crops. Resource allocation for the production of feedstocks is a major issue. There is potential conflict between biofuels and food crops. Energy crops, if grown on a large scale, may compete with food crops for various inputs, including land use, investment requirements, infrastructure support, water, fertilisers and, importantly, agricultural land and water resources, both of which are limited in the region and have to be allocated prudently. A balance in resource (land, water, inputs) allocation between food and fuel production would thus need to be struck. Demand for biofuels could increase the pressure for deforestation by requiring more land for biofuel crops, leading to land degradation. Thus cultivation of biofuel crops may focus on land that would not otherwise be used for food crop cultivation, as well as marginal lands. This will achieve the dual target of land rehabilitation as well as the fuel-related benefits.

Good governance is the key to the establishment of any technology for the good of the people in the region. Because of volatility in some parts of the region, the agricultural potential is not fully exploited, resulting in regional food insecurity. Zimbabwe is a specific case in point—until the mid-1990s, Zimbabwe was the bread basket of the region, supplying seed and grain to most of the other countries regionally. The instability in that country has enhanced the vulnerability of the region to food insecurity, and indirectly limited the options of feedstocks that are available to the region.

Bio-ethanol from maize: a case of biofuel versus food security

While the interest in biofuels has increased in the past few years, a heated debate has ensued on the appropriate feedstock for generation of such fuels. Of particular concern is the use of grain as feedstocks, specifically maize which in the U.S.A. market is thought to have caused an increase in food prices. Maize is a major staple food in Africa; about 95% of maize produced in Africa is for human consumption, and among the 22 countries in the world where maize is the major dietary component, 16 are in Africa. This is exemplified in Zambia, where maize consumption accounts for 58% of total calories in the national diet, and in Malawi, where maize occupies 90% of cultivated land and represents 54% of Malawians' total caloric intake.[35]

Technology for maize-based biofuel is highly developed, particularly in the U.S.A., a major supplier of grain to the world market. The unequal distribution of food on a global scale and drought in some parts of Australia and Asia have reduced global grain supplies, exacerbating the current food insecurity, especially in developing countries. Whether the advent of the biofuel era has improved or worsened the food security situation worldwide is debatable, with two different schools of thought. On the one hand, the argument is that the U.S.A. government's policy of subsidies on maize/ethanol is the major cause of escalating food prices.[36] Unfortunately, bioethanol alone consumed 25% of U.S.A. maize in 2007 and reduced exports to needy parts of the world,[36] especially those relying on food aid.

The other school of thought is that the skyrocketing food and oil prices and increased biofuel production were coincidental.[37] In fact, the rising food prices might be a result of a combination of other causes which are not fuel or food related, such as poor agriculture policies and the changes in eating habits in fast developing economies, such as India and China.[37] According to this argument, 85% of changes in the world's food prices are caused by unreliable weather patterns, increased demand and energy prices, while the remaining 15% have been caused by ethanol production. Increased energy costs usually lead to a cascade of price increases in farm inputs (fertiliser, seed etc.) and food distribution. In addition, food price increases might be partly explained by the devaluation of the US dollar, the international measure of food commodities. The fact of the matter is that production of biofuels has been one of the drivers of food inflation. The use of grain crops, especially maize, to make ethanol has undoubtedly had a negative impact, with the media fuelling the debate on its potential to impact the poor globally.

There is evidence of price distortions of maize, mainly as a result of the opening of the corn industry to market speculations, leading to about a 42% increase in corn prices from 2006 to 2007.[35,36] In South Africa, maize prices increased in line with the world market and so did all the products relying on maize, including dairy and meat. Consequently, food inflation increased by about 22% in South Africa, and even more in neighbouring countries.[37] Moreover, the 2006/2007 drought reduced output by about 40% in South Africa, thus creating a supply bottleneck that increased prices. Based on that argument, one could say that the volatility of maize grain prices on the international market, itself a result, at least in part, of the maize-to-bioethanol production, had a knock-on effect on food security in the region.

The Southern African Biofuels Association (SABA) has a different view. In their paper on the impact of biofuel production on food security, SABA speculated that using maize grain for fuel may in fact stabilise the price in the long term, especially considering that the volatile prices are as a result of a limited market for local maize.[34] Although South Africa is currently producing nine million tonnes of maize annually, this figure is almost equal to the amount consumed. The price therefore varies between import and export parity. Production can, however, be increased to 12 million tonnes with no strain on natural resources. Increasing the local demand through biofuel may therefore ease price volatilities. Considering that maize is not only a staple crop, but a cash crop for small- and large-scale farmers, it makes sense to aim for enhancing the price of maize to benefit the farmers. However, in a country such as South Africa, only a small proportion of the population is actively engaged in farming; the bulk of the population are vulnerable to food insecurity and increased grain prices as they have to buy food. We therefore conclude that maize may not be a suitable feedstock for biofuels in southern Africa, unless special measures are put in place to protect vulnerable groups from basic food price increases. The absence of such measures could potentially lead to unrest and political instability.

Sweet sorghum: a dual-use crop

Sweet sorghum is currently being touted globally as the dual food and fuel crop of the future. Sweet sorghum, also called cane sorghum (*Sorghum bicolor*), contains 10–25% sugar in juice, derived from the stalk at grain maturity.[38] Some of the attractive attributes of sorghum as a biofuel feedstock include the presence of greater genetic diversity[39–41] and its tolerance to abiotic stresses like drought.[42] More importantly, sorghum has half the water requirement of corn and about one-seventh that of sugarcane. These give it a competitive advantage over the two crops for production by resource-poor farmers in the drought-prone areas of southern Africa.[43]

The use of sweet sorghum as a source of ethanol does not compromise food security for the poor, particularly in Africa, since the farmers can continue to use the grain for food. It can be used as a feedstock in the currently-existing sugarcane processing plants for ethanol production, and these are established in southern Africa.

Furthermore, an analysis of the NEBs show some interesting inferences about sweet sorghum, especially when one considers the distance from the point of production to consumption. For sweet sorghum, the processing plants would have to be located in close proximity to the source of the feedstocks, thus promoting local and domestic industry. One could therefore be justified to suggest that in some subtropical areas, such as southern Africa, the NEB of sweet sorghum-derived bioethanol might be higher than the global approximation, especially when used, produced and consumed in the proximity of the feedstock-producing areas. We speculate that the sweet sorghum NEB, if produced in the drier parts of southern Africa, can potentially be higher than that of sugarcane, which is grown under irrigation in many parts of the region, and thus may consume more energy for its production.

The major challenge would be to produce sweet sorghum year-round for continuous processing into liquid fuel. This can be achieved through breeding of cold-tolerant varieties, irrigation and the exploitation of various agroecological regions. With modern biotechnologies such solutions may become reality.

Future outlook

Despite being in early technological development, the potential of biofuels for securing fuel supply for economic development, providing environmentally-friendly energy and alleviating poverty is clear. However, there are many technological, economic and socioeconomic hurdles to overcome. Relevant policies and investment in all aspects of the technology, from research and development to uptake by the market, are essential for the establishment of biofuels. Technologically, much still needs to be done in the establishment of biofuel production (process aspects) and consumption (blending). The fact that most first-generation biofuels are relatively more expensive than fossil fuels speaks to the potential relevance of policies and political will to facilitate increased production and economies of scale. In that respect, governments hold the key in providing incentives through favourable tax regimes that encourage investment into the development of biofuels. Mandatory blending of petroleum products (with biodiesel into petrodiesel or bioethanol into petrol) are examples of such policy strategies. With respect to the limited funding that is directed towards research in most of the countries in the region (excluding South Africa), it is imperative that the private sector be encouraged through various incentive schemes to invest in this area.

While regional countries are trying to promote biofuels to drive economic development, increase their energy security and reduce their fossil fuel carbon emissions and pollution, they are also justifiably concerned that the bioenergy revolution could marginalise the poor, raise food prices and degrade the environment. This is further aggravated by the fact that bioenergy uses resources (land, water and labour) that compete with food production. The food-versus-fuel trade-off will always be an issue with which to contend in cases where innovation and technology investments are largely absent and where trade and subsidy policies are failing. This issue can be avoided if primary/staple food crops are not used for biofuels, and also if biofuel and crop production technology advancements are taken into account. Alternative starch crops and technological advances in cellulosic conversion for biofuel production are worth developing and investing further in. The strong global price increases for root crops like cassava, suggest that without the necessary productivity improvements, aggressive growth in biofuels could have adverse effects on well-being in regions like sub-Saharan Africa, where a large proportion of cassava consumption is for food. Data available suggest that the cost of biofuels could be considerably higher than the projected price of oil, so there would need to be compelling non-price factors for its uptake at the aggressive levels assumed in the first scenario.

On the plus side, the potentially positive role of biofuels for rural development should be encouraged. New crops that are dedicated to oil or oil and food present new agro-enterprises. The establishment of biofuel plants and the processing of byproducts have the potential to stimulate the rural economy. Needless to say though, southern Africa has a rich plant diversity that could be effectively utilised for home-grown biofuel feedstocks, rather than attempt to adapt imported crops and ideas that are not suitable for our environment nor make biofuel ventures worthwhile. Schemes for cost-effective feedstock production in the rural areas should be designed. Subcontracting arrangements that provide farmers with credit and assured price and market, and access to inputs such as fertiliser, hybrid seed and training supplied by the processor, are measures that will couple biofuel production with rural poverty alleviation. The alternative may be a systems approach where small processors located across the country would provide for the local demand and feed the surplus into the national supply system. Such an approach would encompass a franchise business approach or contract farming. With proper controls and standards, a continuous supply of the feedstock and fuel would almost be guaranteed.

Other factors influencing the southern African countries to adopt biofuel strategies, and indeed the nature of such strategies, include national energy security and positive externalities to the environment. If developing economies like those in southern Africa are to participate beneficially in the growth of renewable bioenergy production, and still maintain adequate levels of food security, then a complementary set of investments would need to be made along the lines suggested. By making such investments, these countries are likely to produce benefits for consumers of both food and energy, while also contributing to the broader growth of their economies and the betterment of human well-being.

It is clear that the agenda for biofuels and the demands of food security have led to increased food prices due to the competition for the same raw materials. It therefore follows that a calculated holistic approach to biofuels is needed for southern Africa if the potential of biofuels is to be realised, the foundation of which should be discrimination of feedstocks for food and fuel; crops for use as feedstocks that are suitable to the local environment; proper government policy; and, most importantly, the balance between the competing factors. While the need to respond to climate change is well appreciated, we contend that environmental priorities should not supersede the basic food requirements of the poor. Otherwise, biofuels and the benefits they bring, will remain a pipe dream for the rest of the region.

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