Are Biofuels a real alternative for fuel supply in the developing world or just a perception?

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ABSTRACT

Most countries in the Southern African subcontinent do not produce oil except Angola, South Africa and the Democratic Republic of Congo (DRC). However, oil is a huge socio-economic growth driver in these countries for industrialisation and transportation. These countries operate on high import bills, growing environmental impacts from greenhouse gas (GHG) emissions and global warming leading to climate change. Studies have revealed that one way of addressing these challenges is through the inclusion of Biofuels in the energy supply mix. However, there are competing and conflicting needs which these developing countries are still grappling with such as sustainable food production and food security. This paper considers the real potential of biofuels in developing countries vis-a-vis food production and security challenges. It estimates the pragmatic biofuel production levels that can be achieved without creating food production conflict.

Keywords: *Biofuels, SADC Countries, Feedstock, Food Security, Production Capacity*

1. Introduction

Southern African Development Community (SADC) countries require energy for development and economic growth. Central to their energy supply are fossil-based petroleum fuels imported from markets such as The Middle East, Asia, and Europe (https://wits.worldbank.org/). SADC countries are *price takers.* They grapple with ever-changing fuel prices and shortages amidst economic hardships and challenges. These, and environmental pollution caused by emissions from fuel combustion, make petroleum fuels undesirable and compel the world to remove or reduce their use. In response, SADC, accepted international protocols on climate change and global warming. SADC domesticated these protocols through policies and action plans (SADC, 2010) (SADC, 2012). Some outcomes of 2021 United Nations Climate Change Conference (COP26) are reducing 2030 emissions and limiting global warming to 1.5°C (2.7°F) and end international financing for fossil fuels (UN, 2021). These challenge SADC to rethink its energy self-sustenance which should be met through clean production responding to Sustainable Development Goal number seven (SDG 7).

Albeit energy challenges, SADC is endowed with vast coal resources (Cairncross, 2001). South Africa has been producing fuel from coal since mid-1930’s (United States Environmental Protection Agency, 1980) (Yiming Li, 2019) whilst Botswana plans to do so by 2025 (https://www.spglobal.com/, 2020). However, the process should be *green* and resultant fuels emit less GHGs. Biofuels can help

ISSN: 2521-2293

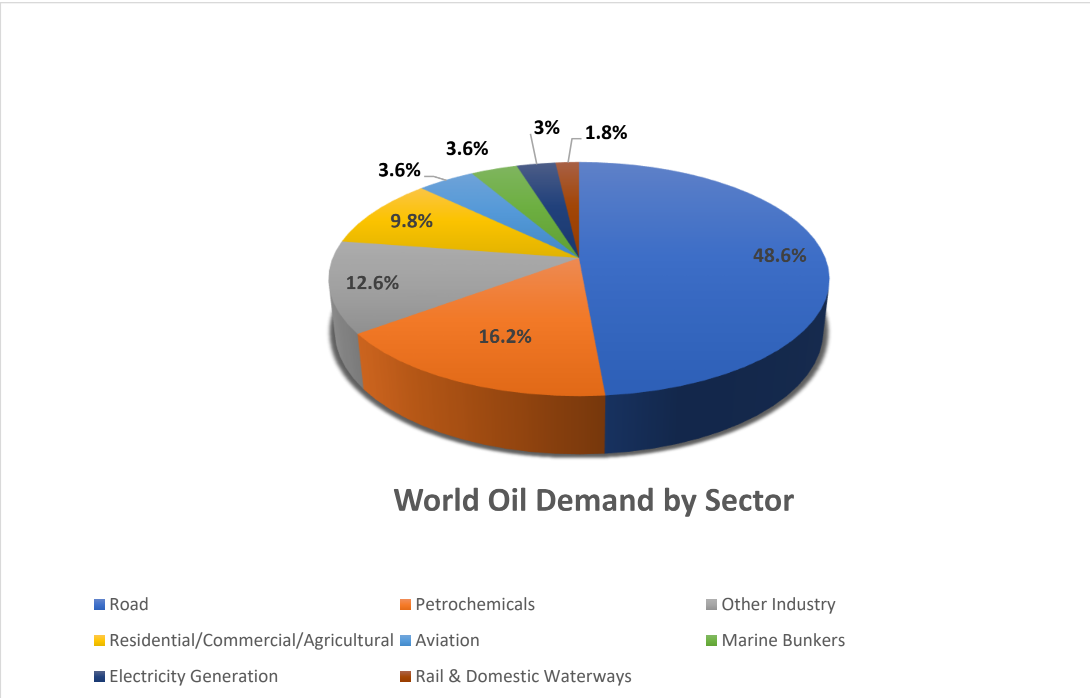
developing countries reach self-sustenance and clean energy (Oladiran , et al., 2011), due to their advantages e.g. low carbon emissions and renewability. Biofuel production requires feedstocks, which are often food production sources. SADC struggles with food security and has numerous droughts and high malnutrition levels. Food unsecured population was 51.3million (15%) of SADC's population in 2020/21 (Centre for Coordination of Agricultural Research and Development for Southern Africa, 2021). Availability of farmland and adequate rainfall are other challenges (Mega Trends in the Southern African Region, 2020). This challenge remains valid whether biofuels are produced from edible or non-edible sources. Even in cases where agro-wastes are feedstocks, agro-production must precede biofuel production. Using waste as feedstock could achieve energy security, GHG emission reduction, pollution control and waste management, thus achieving other environmental and public health goals. Improved waste management could release land required for feedstock farming.

This paper considers realistic biofuel production capacity in selected SADC countries, feedstock availability, energy-food conflict, land availability, food production and policies for biofuel production and use.

Fuel Consumption in SADC

The world's oil demand is 97,103,871barrels/day (Worldometers (https://www.worldometers.info/oil/oil-consumption-by-country/), 2022) of which 48.6% is road transport (Statistica (https://www.statista.com/), 2020). See figure 1 below.

Figure 1: World Oil Demand by Sector, 2020



Source: (Statistica (https://www.statista.com/), 2020)

ISSN: 2521-2293

SADC has 8,618,000,000barrels or 0.98% of world's 1,650,585,140,000 barrels proven oil reserves. Angola makes up 98% of SADC's oil reserves at 8,423,000,000barrels. SADC's oil reserves are an insignificant contributor to global oil production. SADC is a net importer of oil with 950,300barrels/day demand and 285,146barrels/day deficit.

Table 1: SADC Countries Oil Statistics

Country	Daily Oil Consumption (barrels)	World share %	Production barrels/ day	Exports/ day	Imports/ day	Daily Surplus or Deficit (incl. exports & imports)	Oil Reserves (barrels)
South Africa	640,000	0.70%	136,517	9,018	416,531	-95,970	15,000,000
Angola	133,000	0.10%	1,796,743	1,681,354	0	-17,611	8,423,000,000
Tanzania	71,999	0.074%	0	0	0	-71,999	0
Mauritius	28,000	0.029%	517	0	0	-27,483	0
Zimbabwe	24,000	0.025%	189	0	0	-23,811	0
Botswana	21,000	0.022%	0	1	1	-21,000	0
DRC	21,000	0.022%	20,000	16,263	0	-17,263	180,000,000
Malawi	6,001	0.0062%	517	0	0	-5,484	0
Eswatini	5,300	0.0055%	775	0	0	-4,525	0
Total	**950,300**	**0.98%**	**1,955,258**	**1,706,635**	**416,531**	**-285,146**	**8,618,000,000**

Source: (Worldometers (https://www.worldometers.info/oil/oil-consumption-by-country/), 2022)

2. Biofuel Policies in SADC

Biofuel refers to matter derived from organic material, that is burned to produce energy. Common biofuels are; bio-alcohols (ethanol and methanol), bio-gas, bio-diesel or solid bio-mass. Bio-alcohols and biodiesel can be used in vehicles and machinery, bio-gas for heating, cooking and lighting whilst bio-mass for heating, cooking or electricity generation.

South Africa was first in SADC to use biofuels from 1920's to 1960's (GP Von Maltitz, 2008), other countries followed forty years ago: Zimbabwe (1980) and Malawi (1982) (Johnson, 2019). Real interest and commitment to biofuel production started a decade ago when SADC countries established biofuel policies; South Africa (2007), Mozambique (2009) and Angola (2010). Zambia, Malawi and Tanzania followed (United Nations University, 2012). These countries blend fuels depending on availability of biofuels.

South Africa

The South African Biofuels Industrial Strategy targeted 2% biofuel penetration of road transportation fuels (E. Gnansounou, 2007). South Africa set new targets in the Biofuels Regulatory Framework 2019 whose purpose is implementation of the Biofuel Industrial Strategy (Department of Energy, 2019) and has five aspects:

a. Feedstock protocol: mitigates food security risk and prioritises rainwater fed crops.
b. Mandatory blending: minimum 2% bioethanol and 5% biodiesel.
c. Cost recovery: provides and allows cost neutrality of blenders, infrastructure and equipment.
d. Subsidy: provides subsidy to farmers and manufacturers for first generation biofuels only.
e. Selection criteria: objective selection method for projects requiring subsidy considering the socioeconomic benefits.

Tanzania

A task force was set up to develop a National Biofuel Policy, however, due to the time required for policy development, it established guidelines (Jacqueline Cleaver, 2010). Guidelines address; institutional framework, application procedures for investors, land acquisition and use, contract farming and sustainability of biofuel production.

a. Institutional framework: ease of entry into biofuel industry and reducing unnecessary red tapes and institutional bottlenecks whilst creating alignment in the setting up and licensing of biofuel producers.
b. Land acquisition: Tanzania categorises land into two types; village land administered by local councils and general land controlled by Central Government. Village land is not available to investors unless it has been converted to the general land use and the process is lengthy (3years).

Botswana

Renewable Energy Strategy set a target of 20% of total electricity consumption by 2030 (Economic Consulting Associates Limited, 2017), however, it had no specific target for biofuels. The recently promulgated Biofuel Guidelines are to; create a conducive environment, guide investors and stakeholders, provide policy and regulatory frameworks, facilitate development new and innovative

ISSN: 2521-2293

technologies for biofuel production and ensure significant accounting to set standards and requirements. The guidelines are split into technical, economic and policy formulation.

a. Technical: environmental and social impacts, sustainability, project appraisal, feedstock, distribution, and blending.
b. Economic viability: estimated cost of production.
c. Policy formulation: institutional framework, permitting and licensing procedures, incentives, land acquisition and use, contract farming, quality and blending.

Zimbabwe

Zimbabwe Biofuels Policy targets 2% and 20% blending for biodiesel and bioethanol respectively by 2030 (Ministry of Energy and Power Development, 2015). Its objectives are to:

a. Improve viability, long-term growth and sustainability;
b. Ensure maintenance of bio-fuel product quality and standards;
c. Improve productivity and economic viability of bio-fuel feedstock;
d. Implement development trajectories balancing bio-fuel investments with biodiversity maintenance, water and air pollution;
e. Implement production models that increase community benefits and foster institutional cooperation and coordination.

Between the 1980's and 1990's Zimbabwe produced ethanol from molasses with blending of up to 15%. Production continually suffered setbacks of droughts. Recently mandatory blending of 10% was introduced, however its implementation depends on availability of feedstock.

Eswatini

In 2009, the Government established National Biofuels Development Strategy and Action Plan. The strategy provides guidance for the development and nurturing of the biofuels industry (Ministry of Natural Resources and Energy, Swaziland, 2009). The strategy recognises that development of biofuels is challenging making it uneconomic when international oil prices are favourable. It recommends a phased implementation plan considering the inadequate resources and calls for a biofuel regulator.

Eswatini has produced bioethanol in the past from its sugarcane production, however delayed biodiesel production for inadequate feedstock research.

Malawi

Malawi used biofuels from 1980's and blended up to 20% for bioethanol and 9% for biodiesel. Biofuels contribute 4% of Malawi's transport energy consumption (Ministry of Natural Resource, Energy and Mining, Malawi, 2018). The Energy Policy prioritises biomass and biofuels and targets to reduce over-reliance on biomass by rolling out efficient cooking stoves. It promotes biofuels production without compromising food security and aims to provide fiscal and pricing incentives to encourage biofuels production and use. It considers large projects for biofuels production, flex vehicles and introduction of biofuels compatible infrastructure e.g. pumps.

Angola

Angola's Atlas and National Strategy for the New Renewable Energies recognises that biomass could generate more than 3GW energy. Depending on technology used sugarcane potential ranges between 1.1 and 2.9kW whilst 120MW has been mapped for municipal waste around major urban areas (Ministry of Energy and Water, Angola). Biomass resource is suitable for mini grids, small engines and biodigesters. It determines the costs for biomass energy projects as high as US$1,880/kW – US$6,800/kW, identifies the levelised cost of energy (LCOE) range (US$0.06/kWh – US$0.2/kWh) and sets renewable technology targets though not specifying biofuels outside the earmarked biomass power projects.

Mauritius

Mauritius established a Long-Term Energy Strategy, 2009 – 2025 which recognises the abundance and role of biomass from sugar cane for electricity generation. It aims to diversify diesel supply with biodiesel manufacturing and proposes biodiesel importation considering inadequate feedstock for local production. It proposes 10% ethanol blending increasing to 20% later based on available 150,000tonnes of molasses, estimating 120,000tonnes for producing 25 million litres ethanol.

3. Biofuel Production Trends

In 2020 global ethanol production was 26.06billion gallons dropping from 29.03billion gallons in 2019 (US Department of Energy: Energy Efficiency Renewable Energy, 2021). United States of America (USA) and Brazil makes 84% whilst 16% is shared between European Union, China, Canada and the rest of the world. Africa produced 400barrels/day ethanol in 2012 (Index mundi, 2012). 50% being Malawi and the rest from South Africa and Ethiopia. European Union produces 32.3% of the world's biodiesel followed by USA: 18.1%, Indonesia: 15%, Brazil: 12.2% and 13.63% shared between China, India, Canada, Argentina, Thailand, Colombia and Paraguay (FAO, 2021). Despite its potential, Africa does not feature in the world biodiesel statistics.

4. Research and Education

Scholars continue to publish work on biofuels ranging from feedstock analysis to production and analysis of biofuels and engine performance including technologies used to produce biofuels. (Gnansounou, et al., 2007) (Jonas, et al., 2020) (Oladiran , et al., 2011) Governments support research, e.g. in Botswana, Department of Energy supports Biogas and Biodiesel researches and previously partnered with the Japanese Government for the jatropha research.

Evolution of biofuels and their success should follow thorough research and well-established policies and strategies.

5. Quality Standards

Biofuel quality is important in determining performance of vehicle or equipment. Ideally biofuel properties should be like those of conventional fuels for seamless interchangeable use and mixing. Quality standards set limits for the critical parameters within which biofuels should be produced. They specify test methods and procedures for ascertaining product quality.

Some SADC countries have developed standards to address quality of biofuels. Table 2 indicates the various standards applied in SADC. However, all SADC countries have functioning Standards Organizations (e.g. BOBS, SABS, SAZ for Botswana, South Africa and Zimbabwe respectively) which can create quality standards for biofuels.

Table 2: Technical & Quality Biofuel Standards in SADC Countries

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Country	Standard (s)
Botswana	BOS626 Automotive Biodiesel
Eswatini	SZNSSANS 1935 Automotive biodiesel SZNS019 Standard specification for denatured fuel ethanol - blending SZNS054 Standard Specification for 10 volume % Ethanol Gasoline Blend
Malawi	MS805 BIODIESEL FUEL – SPECIFICATION MS845 Biodiesel flue-Specification MS573 ETHANOL – SPECIFICATION
Mauritius	MSEN15376 Automotive fuels - Ethanol as a blending
South Africa	SANS833 Biodiesel production - Quality management system SANS1935 Automotive biodiesel SANS465 Automotive fuels - Requirements and specifications for fuel ethanol - blending SANS1462 Automotive fuel ethanol - Quality management system
Tanzania	TZS1104 Ethanol Gel for domestic Heating TZS1099 Automotive biodiesel fuel
Zimbabwe	ZWS719 Biodiesel fuel blend stock (B100) ZWS968 Diesel fuel oil, biodiesel blend (B5 to B20) ZWS962 Denatured fuel ethanol - blending ZWS964 Ethanol (Parts 1 – 15) ZWS1020 Part 2 Biogas Systems

6. Feedstocks

SADC countries could each produce biofuels depending on feedstocks capacity to complement each other. Land scarcity and food security challenges should be well taken care of.

Angola

Angola considered four feedstocks: forestry residues and energy crops, agro-food industry residues (sugarcane), farming activity residues and solid waste. Forestry resource potential is 50MW by estimating annual increases of biomass/ha. The sugarcane potential areas were determined from large areas with at least 10,000ha and without environmental restrictions but with high irrigation potential. Agricultural and livestock waste was also considered. Solid waste was considered by using population statistics quantifying waste/capita and its energy potential.

Botswana

Jathropha has been studied for biodiesel production whilst other studies considered non-food indigenous plants for food security concerns and climatic conditions. Recent studies are focusing on production of biodiesel from animal tallow considering the country's beef industry. Recently through the support of the United Nations Development Programme (UNDP) biogas digesters were constructed for farmers. Waste from landfills can be explored, however, it includes other forms that are not biodegradable. This reason and the amount of waste per landfill makes it unattractive for investors. Efforts to produce 106,000tons sugar/annum from 100,000ha with sugarcane were thwarted by an Environmental Impact Assessment (EIA) for forest reserve conservation concerns.

Eswatini

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Eswatini is third largest producer of sugarcane in Africa and produces at least 60million litres ethanol (International Renewable Energy Agency, 2014) and plans to increase production to meet E10 blending. Biodiesel from jatropha was attempted with plans to cultivate 10,000ha in 10 years and supply 13million litres biodiesel. It was aborted due to lack of investment when the initial company ceased operations (Ministry of Natural Resources and Energy, Swaziland, 2009).

Malawi

Malawi reached 20% and 9% blending levels for ethanol and biodiesel respectively. Sugarcane is used for ethanol while jatropha for biodiesel. Malawi's Energy Policy prohibits the use of food crops for biofuels. Due to deforestation, it is not advisable to consider forestry biomass.

South Africa

Maize, sorghum, sugarcane, canola, soybean and sunflower were considered. Due to food security maize is excluded because it is a staple food for both humans and cattle. Sorghum production has been declining due to reduced demand. Sugarcane is considered better and has potential to produce ethanol, sugar, electricity, and other by-products. Canola is not well understood and was abandoned whilst sunflower had to be modelled for water use and yield. Soybean is selected.

Tanzania

Sugarcane, sorghum, cassava and sisal are potential feedstock for ethanol (German Technical Cooperation (GTZ), 2005). Ethanol can be produced from sugar or molasses. Sugarcane bagasse can also generate electricity thereby increasing the overall efficiency. Sisal production trails to the 1950's for fibre twine production. However, useful fibre constitutes only 2% of the plant and the rest waste and bole. Sisal waste could be used for biogas production. Bole is rich in pulp and liquid juice which has been studied for ethanol production. Sunflower, palm, various nuts, coconut, avocado have been studied as biodiesel feedstocks and have good yields. Jatropha has been identified since it is non-food and is widely spread and adapted to the climatic conditions.

Zimbabwe

Biofuels Policy identifies sugarcane, cassava and sweet-sorghum as feedstocks for ethanol whilst jatropha for biodiesel (Ministry of Energy and Power Development, 2015). The 10% blending could be achieved through jatropha production (Raphael M. Jingura, 2011). The situational analysis conducted by the Worldwide Fund for Nature (Enos Shumba, 2009) affirmed sugarcane and jatropha as suitable feedstocks for biofuels.

Table 3: Summary of selected feedstocks for SADC countries

Country	**Biodiesel**	**Ethanol**
Angola	Jatropha	Sugarcane
Botswana	Jatropha, animal tallow, waste oil	Sweet-sorghum
Democratic Republic of Congo	Palm Oil	Cassava
Eswatini	Jatropha	Sugarcane
Malawi	Jatropha	Sugarcane
Mauritius		Sugarcane
South Africa	Soybean	Sugarcane, sweet-sorghum
Tanzania	Jatropha	Sugarcane, sorghum, and sisal
Zimbabwe	Jatropha	Sugarcane

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Sugarcane leads followed by sweet-sorghum as ethanol feedstocks whilst jatropha is for biodiesel in SADC. These are selected based on low or no competition with food, ease of cultivation, climatic conditions, and adaptability to a particular country. Therefore, determining the overall potential of biofuel production for a particular country should be based on the condition that current production and uses of feedstock are not disturbed.

7. Land Availability

Feedstock production requires land which is also used for other purposes e.g. residential, wildlife, food production, forest sanctuaries etc. Land is amongst the world's most scarce resources and under pressure as human population grows, human needs change e.g. rapid urbanisation and mining, and world's consciousness towards conservation (wildlife and forests). This affects SADC which is endowed with natural resources ranging from minerals, wildlife and world heritage sites and is dependent on farming activities.

Angola

Angola has 57million hectares agricultural land or 45.6% of total land area. 61.4% (35million hectares) is arable land whilst only 16% (5.6million hectares) is cultivated (The World Bank, 2021). 29.4million hectares of arable land remain uncultivated and available for food and energy production.

Botswana

Statistics Botswana, 2019 reported total arable land as 117,416ha. 75.2% (88,288ha) were cultivated (Statistics Botswana, 2020). However, this excludes the commercial sector. The African Development Bank reported 155,699ha planted in 2019 (African Development Bank, 2021) against 259,562.34ha arable land (The World Bank, 2022) for both commercial and traditional sectors.

Democratic Republic of Congo

DRC has 226,705,000ha land area. 31,500,000ha (13.9%) is agricultural land (Food and Agriculture Organisation of the United Nations, 2022). Arable land is 5.205% of land area (11,800,000ha) (The World Bank, 2022). AfDB recorded 13,380,657.80ha harvested area in 2018 (African Development Bank, 2021).

South Africa

South Africa's land area is 121,309,000ha. Agricultural land is 96,341,000ha (79.4%) (Food and Agriculture Organisation of the United Nations, 2022). Arable land is 9.892% (11,999,886.28ha) (The World Bank, 2022). In 2020, 6,557,050ha (54.6% arable land) were cultivated with summer crops whilst 1,986,940ha were winter crops (Department of Agriculture, Land Reform and Rural Development: South Africa, 2021).

Tanzania

Tanzania's land cover is 88,580,000ha and 39,650,000ha (44.8%) is agricultural land (Food and Agriculture Organisation of the United Nations, 2022). 15.24% (13,499,592ha) land area is arable (The World Bank, 2022). In 2018, 11,043,509.67ha (81.8% arable land) was cultivated (African Development Bank, 2021).

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Zimbabwe

41.9% (16,200,000ha) of Zimbabwe's 38,685,000ha land area is agricultural (Food and Agriculture Organisation of the United Nations, 2022). Arable land is 10.34% (4,000,029ha) land area (The World Bank, 2022) whilst 1,740,085.177ha was cultivated in 2018 (African Development Bank, 2021).

8. Feedstock Yields

Feedstock yield is crucial in determination of biofuel potential. The yields are determined firstly as the fuel content per tonne ($L * 1000kg^{-1}$) e.g. litres ethanol/tonne of sugarcane, then agricultural yields ($1000kg * ha^{-1}$) e.g. tonnes of sugarcane/hectare and finally fuel content/hectare ($L * ha^{-1}$) e.g. litres of ethanol/hectare.

Sugarcane

The industrial yield of anhydrous ethanol is 85litres/tonne of sugarcane for standard distillery (Marina Oliveirade Souza Dias, 2015). When optimised it is 88L/ton. The agricultural yield is 71 tonnes/hectare (Marina Oliveirade Souza Dias, 2015). The calculated fuel content/hectare is 6,035litres/hectare, below the GTZ's 7,561L/ha (German Technical Cooperation (GTZ), 2005).

Sweet-sorghum

Sweet-sorghum's yield can reach 8,000L/ha, i.e. 30% higher than sugarcane yield (Daniel E. Ekefre, 2017). Ekefre et al. 2017 calculated the lowest yield for Dale as 5,077L/ha and the highest for Theis as 7,619L/ha (Daniel E. Ekefre, 2017).

Cassava

Ademiluyi and Mepba 2013, determined the ethanol yields for cassava as 150L/ton for fresh tubers and 333L/ton for dry chips (Mepba, 2013). GTZ 2005, determined ethanol yield for cassava as 1,702L/ha (German Technical Cooperation (GTZ), 2005).

Sorghum

Ramirez et al. 2016 concluded that for lower solid to liquid ratios i.e. 1:5 & 1:4, ethanol yield ranged between 355L/ton and 368L/ton. Increasing ratio to 1:3 dropped yield to 305 – 325L/ton (2016). GTZ 2005, determined ethanol yield for sorghum as 325L/ha (German Technical Cooperation (GTZ), 2005).

Jatropha

Demafelis and Angeles 2009**,** estimated the jatropha yields in Thailand as 3 – 4 ton/ha, agricultural yield and 30 – 35% oil yield (Angeles, 2009). M. Jonas et al. 2020, determined the oil yield for jatropha to be 38.7 – 45.8% (Jonas, et al., 2020). GTZ 2005, stated the oil yield for jatropha as 1,892L/ha (German Technical Cooperation (GTZ), 2005).

Palm Oil

Palm oil yield is 5,950L/ha (German Technical Cooperation (GTZ), 2005).

SoyBean

Soybean oil yield is 446L/ha (German Technical Cooperation (GTZ), 2005). In South Africa the agricultural yield for soybean was reported to be 2.5 – 3ton/ha (Department of Agriculture, Forestry

ISSN: 2521-2293

and Fisheries, South Africa, 2010) whilst the biodiesel yield is 171.4L/ton (Sparks, et al., 2010). Combining the two, 428.5L/ha is obtained, close to 446L/ha reported by GTZ 2005.

9. Estimated Biofuel Potential

In estimating biofuel potential fuel consumption, food requirements, land required for food production and biofuel production were considered. Fuel consumption was split between petrol and diesel assuming they are equal for ethanol and biodiesel production respectively Arable land was divided by subtracting the land required for a country to be food secure and land already used for crop production. Then, land required for biofuel production was subtracted. Where the resultant was a negative number or very close to zero it was concluded that land is unavailable for biofuel production. For countries where available land is more than enough to produce biofuels then consideration was made for additional production to supply the region. Land required for biofuel production was determined by dividing the biofuel demand by the biofuel yield/hectare.

$$\text{Land required for biofuel production} = {}^{biofuel\ demand}\!/_{biofuel\ yield\ per\ hectare}$$

Potential biofuel production for SADC was determined for countries which have adequate arable land. These countries: Angola, Madagascar, Mozambique, South Africa, Tanzania, Zambia and Zimbabwe could produce SADC's fuel requirements by releasing 4.5% of their unused arable land additionally to land required for them to be fuel and food secure. 33.55billion litres biofuels/year could be produced from 34.25million hectares. Additional 4.5% (1.8million ha) of land, would increase production by 4.8billion litres resulting in 38.3billion litres against SADC's 37.95billion litres fuel demand (Index mundi, 2012). Food farming would not be a problem because the balance of arable land under this scenario would be 38.6million hectares. Other SADC countries are considered not to have sufficient land for both food and biofuels. See Table 4.

Table 4: Biofuel Potential in SADC Countries

Country	A. Total food production (Oxford Martin School, 2020) Tons	B. Annual food required (1.5kg/person (Bloomberg, 2020) * population*365) Tons	C. Deficit/surplus food (A – B) Tons	D. Additional Land required for food production (C/(A/cultivated land (African Development Bank, 2021))* Ha	E. Annual Fuel demand (Index mundi, 2012) Litres		F. Biofuel land requirement (E / Yield (German Technical Cooperation (GTZ), 2005)) Ha		
					E1. Gasoline	E2. Gasoil	F1. Ethanol	F2. Biodiesel	F3. Total
Angola	19,991,124	17,994,282	1,996,842	-	1,450,756,375	3,191,664,025	191,874	1,686,926	1,878,800
Botswana	56,907	1,287,515	-1,230,608	3,366,974	475,848,091	475,848,091	93,726	251,505	345,232
DRC	39,724,899	49,034,648	-9,309,749	3,135,831	348,181,530	533,878,346	204,572	89,727	294,299
Eswatini	5,854,566	635,190	5,219,376	-	121,863,536	127,666,561	16,117	67,477	83,594
Malawi	22,656,841	10,473,650	12,183,191	-	104,454,459	168,287,740	13,815	88,947	102,762
Mauritius	3,187,379	692,993	2,494,386	-	168,287,740	377,196,658	22,257	-	-
South Africa	59,740,922	32,643,045	27,097,877	-	11,489,990,490	12,940,746,865	1,519,639	29,015,128	30,534,767
Tanzania	39,657,501	32,704,482	6,953,019	-	429,423,887	1,044,544,590	56,795	552,085	608,879
Zimbabwe	6,084,093	8,137,453	-2,053,360	587,272	237,924,046	533,878,346	31,467	282,177	313,644
Total	**196,954,232**	**153,603,258**	**43,350,974**	**7,090,077**	**14,826,730,154**	**19,393,711,222**	**2,150,262**	**32,033,972**	**34,161,977**

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Table 5: Additional Biofuel Potential in SADC Countries

Country	G. Available land (Arable land (The World Bank, 2022) – F3) Ha	H. Biofuel Potential Litres	I. Additional Land (4.5%*G) Ha	J. Additional Fuel from additional land Litres		K. Total Biofuel Potential Litres	L. Balance Land (G -I) Ha
				J1. Ethanol (15%*I*H1)	J3. Biodiesel (85%*I*H2)		
Angola	29,400,000	4,642,420,400	1,323,000	1,500,480,450	2,127,648,600	3,628,129,050	28,077,000
Botswana	No land	-		-	-	-	-
DRC	No land	-		-	-	-	-
Eswatini	No land	-		-	-	-	-
Malawi	No land	-	-	-	-	-	-
Mauritius	31,615	-	-	-	-	-	-
South Africa	3,454,896	24,430,737,355	155,470	176,326,678	58,938,803	235,265,481	3,299,426
Tanzania	2,456,082	1,473,968,477	110,524	125,350,460	177,744,222	303,094,682	2,345,559
Zimbabwe	1,672,671	771,802,392	75,270	85,367,708	121,049,551	206,417,260	1,597,401
Total	**37,015,264**	**31,318,928,624**	**1,664,264**	**1,887,525,296**	**2,485,381,176**	**4,372,906,473**	**35,319,386**

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10. Development

International Renewable Energy Agency (IRENA) and SADC Centre for Renewable Energy and Energy Efficiency (SACREEE) in 2017 launched SADC Entrepreneurship Support Facility, aimed at supporting renewable energy market development through training, mentorship, and linkage to financial institutions (IRENA, 2021). Financial institutions such as commercial banks, multilateral development banks and non-banking financial institutions should setup facilities for funding biofuels development. Governments and energy regulators should introduce incentives for biofuel development. Such incentives should be administered by independent regulators for fair distribution.

Capacity building initiatives will be required to develop human resource capital in the field of biofuels. Policies studied at section 2 indicate that some governments have put in place incentive mechanisms to help develop the biofuel market in SADC. Governments should provide adequate resources such as infrastructure, blending mandates and standards to increase the uptake of biofuels.

11. Conclusions

SADC has potential for both sufficient food and biofuel production considering arable land available and feedstock yields. Four countries (Angola, South Africa, Tanzania and Zimbabwe) could produce 35.7billion litres/annum from (35million hectares) 54% of their total arable land. However, rainfall patterns, irrigation possibilities, production technologies and costs were not assessed.

Countries with inadequate land could produce second generation biofuels. Though not analysed, Botswana and Namibia could use waste tallow for biodiesel production. Agro-waste and algae were not assessed but have potential to increase biofuel production capacity.

Analysis of naturally occurring feedstock was not done. For example, in Botswana some indigenous plants can be used for biofuel production, their potential production capacity could be assessed.

Malawi has successfully blended conventional fuels with biofuels for four decades, this is an indication that biofuels are not just a perception. If well developed and sustainably produced biofuels could gradually replace petroleum fuels.

ISSN: 2521-2293

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