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Biofuel developments in Mozambique. Update and analysis of policy, potential and reality

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ABSTRACT

Climate change, rising oil prices and concerns about future energy supplies have contributed to a growing interest in using biomass for energy purposes. Several studies have highlighted the biophysical potential of biofuel production on the African continent, and analysts see Mozambique as one of the most promising African countries. Favorable growing conditions and the availability of land, water and labor are mentioned as major drivers behind this potential. Moreover, the potential of biofuel production to generate socio-economic benefits is reflected in the government's policy objectives for the development of the sector, such as reducing fuel import dependency and creating rural employment. This article provides an overview of biofuel developments in Mozambique and explores to what extent reality matches the suggested potential in the country.

We conclude that biofuel developments mainly take place in areas near good infrastructure, processing and storage facilities, where there is (skilled) labor available, and access to services and goods. Moreover, our analysis shows the need to timely harmonize current trends in biofuel developments with the government's policy objectives as the majority of existing and planned projects are not focusing on remote rural areas, and – in absence of domestic markets – principally target external markets.

1. Introduction

Increases in the price of fossil fuels, and growing concerns regarding their finite availability, use and impacts (including climate change) have driven the demand of biomass for energy purposes worldwide (Commission of the European Communities, 2006; van Dam et al., 2008, 750). Biofuels are perceived to be a good alternative to fossil fuels and 'a pathway out of poverty' for developing countries. Biofuels may provide new incentives for investments in agricultural research and development, offer farmers a new source of income (Smeets et al., 2007, 103–104), and stimulate linkages to input and food markets that currently do not exist (FAO, 2008b). On the other hand, concerns raised in the food-fuel-feed debate provide a good example of how biofuel production might lead to competing claims on land, water, labor, and other resources.

Like many other countries, Mozambique has explored the potential for renewable energy options to meet its energy needs (Jumbe et al., 2009). There is a growing interest in the production of biomass for biofuels, and large-scale, mainly foreign investments have been made. Evidence of Mozambique's biophysical suitability for biofuel feedstocks exists with the long-term presence of sugarcane plantations in different parts of the country. As the first biofuel projects are becoming tangible, there is a need to monitor and analyze the factors that are driving the direction of biofuel developments in Mozambique; exploring to what extent reality matches the suggested potential in the country.

2. Background on Mozambique

Mozambique is one of the fastest growing economies in sub-Saharan Africa, with a growth of around 7% per annum since the early 1990s (World Bank, 2008). Although poverty rates had dropped from 69% in 1997 to 54% in 2003 (Arndt et al., 2008a, 1), Mozambique is still among the world's poorest countries. On the August 2007 U.N. Human Development Index (USAID, 2009b) it ranked 172 out of 182 countries, the lowest among the 14 Southern African Development Community (SADC). Average income levels are low, with a GDP per capita of US$364 in 2007 (World Bank, 2008). The country has approximately 21.4 million

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inhabitants with an average life expectancy of 42 years at birth (World Bank, 2008). Prevalence of malnourishment in the total population was 44% between 2002 and 2004 (FAO, 2008a, 17). For 2007, the HDI indicated adult literacy rates of 44.4% for the population of 15 years and above (UNDP, 2009).

Despite its relatively high rates of economic growth, Mozambique still faces widespread poverty which is claimed to be the result of historical factors including the Portuguese colonization and armed conflicts that uprooted social networks and destroyed most of Mozambique's commercial and transport infrastructure, educational and health systems. Moreover, the country is vulnerable to natural disasters (floods and droughts); is facing limited and uneven market development; rural–urban differentiation; and socio-economic differentiation in relation to control and access to assets (particularly land). According to De Matteis et al. (2006, 7), 35% of the population is highly vulnerable to food insecurity, which besides food availability is believed to be a result of the ineffective access, storage and distribution of food (cf. Arndt et al., 2008b; Batidzirai et al., 2006, 55; USAID, 2009a). Despite having much more propitious agro-climatic conditions, vulnerability to chronic food insecurity is highest in the Northern provinces.

Mozambique stretches 2500 km along the coast of southeast sub-Saharan Africa and has a land area of 799,390 km^2 (PARPA II, 2006). Of this land area, 36 million ha are arable, of which approximately 10% is under cultivation (FAO, 2007). Because of the country's fertile lands and favorable climate, Mozambique is attractive for agriculture, which employs 80% of the estimated 8.8 million labor force (African Development Bank, 2008, 3; Econergy, 2008, ES4). The remaining 20% is involved in the industrial, transport, communication and service sectors (World Bank, 2009).

As Mozambique is 100% dependent on oil imports (FAO, 2008a, 17), a considerable and increasing amount of the total GDP is being spent on fuel and energy; 10% of the total value of imports in 1997, 15% in 2006 and 17% in 2007 (World Bank, 2008), which explains the government's interest in exploring alternative energy sources, such as biofuels.

3. Biofuel time-line in Mozambique

The biofuel discussion in Mozambique became prominent in 2004. During the election campaign, the government encouraged Mozambican farmers to produce Jatropha on all unused, marginal soils so Mozambique could become an oil exporting country instead of being wholly dependent on oil imports. The government promised that: "Biofuels will not displace Mozambican farmers from their lands, and that government policy would require the use of underutilized or empty lands, would avoid using lands allocated for food production, and that Mozambique will refine its own raw materials." (Frontier Markets, 2008). The initial idea was that 5 ha of Jatropha were to be planted in each of Mozambique's 128 districts. The Mozambican extension service started sourcing Jatropha seeds, mainly from Malawi. Most of the seeds were of poor quality; they had been stored for a long time and often under adverse conditions, resulting in low germination rates (TechnoServe and ICRAF/IIAM, 2006, 18). Apart from distributing the seed, there was lack of real follow-up, hence crop maintenance was neglected, and many plants died. The few farmers who produced Jatropha seeds did not know what to do with them, as organized markets and supply chains were absent. Nevertheless, the promotion of biofuels by the Mozambican government had by that time attracted numerous private investors as well as some biofuel-related development projects. Plantations of Jatropha were established with only limited information available regarding seed varieties, good agronomic practices, production systems, markets and scale of operations. In addition, the belief that Jatropha hardly requires nutrients for its growth and is drought resistant stimulated investments on marginal land, which later turned out to be unsuitable for growing Jatropha.

While interest in Jatropha as a 'miracle crop' spearheaded the political promotion of biofuels, there was also significant private sector and government interest in the production of ethanol. The principal feedstock considered was sugarcane, although an increasing level of interest began to be shown in sweet sorghum over the last 2 years.

Concerns about potential pressure on land, water, food production and lack of control over this process resulted in an intense discussion between government, private sector, NGOs and academics. As a result, large-scale land-requests were frozen between October 2007 and May 2008, while the government undertook agro-ecological land zoning. The first biofuel project in Mozambique was approved in October 2007; since then, three more large-scale projects have been formally approved by the government. In March 2009, the Mozambican government approved a national policy and strategy for biofuels. In December 2009, the government voided the contract of one of the approved companies, as they failed to comply with their contractual obligations.

4. Theoretical framework and methodology

Over the last years, several studies have highlighted the (biophysical) potential of biofuel production on the African continent (Batidzirai et al., 2006; Diaz-Chavez and Jamieson, 2008; Smeets et al., 2007). Mozambique is seen by analysts as one of the most promising African countries for biofuel production, as it has abundant and unexploited land and water resources. These projections have provided strong arguments for the promotion of biofuel production in Mozambique. Although we acknowledge the importance of studies on biophysical potential, we believe there are other drivers that determine how and where biofuel production in Mozambique could be successful. Investment theory explicitly studies the relative importance of specific biophysical, socio-economic and legal factors that guide investment location decisions (Davidson, 1980; Wheeler and Mody, 1992). As these factors are sector dependent (Wheeler and Mody, 1992), and biofuels form an emerging sector, it is important to understand and analyze the variables which are dominantly driving the direction of biofuel developments in countries like Mozambique. Moreover, mapping the current biofuel developments vis-à-vis long-term policy objectives for promoting biofuels, allows for the timely and adequate development and implementation of policy tools to harmonize investor and government objectives.

The objective of this paper is to integrate, analyze and visualize knowledge from different disciplines to show how dynamics between biophysical potential, policy and legal frameworks, and socio-economic factors need to be understood to explain current biofuel developments in Mozambique (Fig. 1). By doing so, we hope to complement existing studies and provide additional insight in the complexities that are driving the direction of biofuel developments in Mozambique. Our efforts to integrate knowledge from different disciplines in the form of maps were inspired by the idea that such visualisations could serve as boundary objects (cf. Ewenstein and Whyte, 2009).

To reach our objectives, we present various forms of data. Firstly, we conducted a literature study to analyze multiple sources of secondary data; scientific reports and papers on biofuel potential, biofuel-related policy documents, and media reports related to biofuel developments in Mozambique. Secondly, we analyzed investment data in collaboration with the Agriculture Promotion Centre (CEPAGRI) of the Ministry of Agriculture of

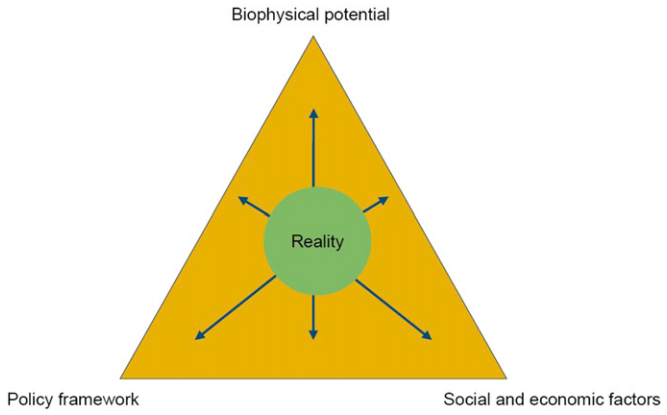

Fig. 1. Framework to analyze the drivers of biofuel developments in Mozambique.

Mozambique. Thirdly, we undertook geographical mapping of biofuel developments in Mozambique. This inventory includes the operational biofuel projects and expressions of interest throughout the country, as well as existing and planned biofuel-related processing and storage facilities. This data was complemented with information collected from ten field visits to both commercial and smale-scale biofuel projects, and more than and 50 interviews with policy-makers, investors, farmers, NGO representatives and researchers.

5. Policy framework for biofuel developments

This section identifies and discusses the (inter)national policies, agreements and legislation related to biofuel production, processing and trade in Mozambique. Subsequently we look at how incentives and restrictions established in these policies could influence the development of the biofuel sector in Mozambique.

5.1. Trade agreements

Mozambique is a signatory to several trade agreements that establish the terms and conditions for access of Mozambique's potential biofuel production to key regional and international markets, namely the EU, the US and SADC (cf. Rebello Da Silva and Da Silva Garrilho, 2003, 84–85).

Access to the EU market for biofuels is granted under two key agreements: (1) the Cotonou Protocol between the EU and African, Caribbean and Pacific countries, which is in the process of being transformed into a regional economic partnership agreement (EPA) between the EU and SADC and (2) the 'Everything But Arms' arrangement which grants duty-free access to the EU market for all goods (except arms) for least developed countries. As a result, duty-free access is provided for ethanol, biodiesel, and vegetable oil exports from Mozambique to the EU. However, only ethanol and biodiesel produced in compliance with the EC's recently published sustainability criteria will be eligible for the market incentives for biofuels sold on the EU market.

Mozambique also has duty-free access to the US market under the Generalized System of Preferences (GSP) which grants reduced duty or duty-free access to developing countries. This was extended by the African Growth and Opportunity Act (AGOA) in 2000, a United States Trade Act that significantly enhances US market access for (currently) 39 sub-Saharan African countries, including Mozambique.

The SADC Trade Protocol is an agreement between eleven SADC members[1] aimed at promoting regional trade in the bloc. Under this agreement, tariffs on intra-regional trade of certain goods have been eliminated or substantially reduced. Tariffs on so-called 'sensitive goods' are to be eliminated by 2012, although final details remain under discussion, and Mozambique has until 2015 to comply. When fully implemented, the protocol will give Mozambican products duty-free access to a market of over 200 million people with a GDP of US$275 billion, with reciprocal treatment for the goods from the other members (Embassy of the United States, 2006). However, in the case of biofuels, the final size of the regional market, and Mozambique's access to it, will depend on the establishment of harmonized fuel standards and blending mandates or authorization in the other member countries.

5.2. Land law

According to the Constitution, all natural resources in Mozambique, including land, belong to the state. Land acquisition procedures are governed by the Land Law (Law No. 19/97 of 1 October 1997) and its Regulation (Decree No. 66/98 of 8 December 1998) and culminate in the attribution of a 50-year renewable lease in the form of a land title or Direito de Uso e Aproveitamento dos Terras (DUAT). Article 3 of the Land Law states that: "Land is the property of the State and cannot be sold or otherwise alienated, mortgaged or encumbered", and establishes three means of acquiring land:

1. through existing occupation established by customary norms and practices (Land Law Article 12 and Regulation of the Land Law Article 9). This includes used and unused (fallow and common) lands that a rural household needs to have access to and control over for a certain period of time;
2. through existing occupation 'in good faith' (Land Law Article 12 and Regulation of the Land Law Article 10) when people have occupied the land for at least ten years without challenge, which aims to protect the rights of displaced persons that settled in lands during the civil war that were formerly owned by colonial powers; and
3. through a formal request to the State (Land Law Article 12 and Regulation of the Land Law Article 11).

Article 13 of the Land Law and Article 27 of the Regulation of the Land Law state that formal requests to the State must be accompanied by a community consultation, which seeks to ensure that community rights are taken into account and provides an opportunity for communities to negotiate some element of compensation or benefit with investors. The Land Law (Article 11) and its Regulation (Article 18) require that foreigners have an approved investment project in order to apply for a DUAT.

Land-requests submitted to the government are evaluated initially by the relevant government departments that oversee the activity at provincial level (Regulation of the Land Law Article 24 (2) and Article 26 (1)). When the area requested is greater than 1000 ha and therefore no longer the remit of the Provincial Governor alone, evaluations are requested from the relevant government departments at national level, and requests have to be authorized by the Minister of Agriculture (Regulation of the Land Law Article 26 (3)). Where proposals involve areas of more than 10,000 has or investment values greater than US$100 million, they have to be submitted to the Economic Council

[1] Botswana, Lesotho, Malawi, Mauritius, Mozambique, Namibia, South Africa, Swaziland, Tanzania, Zambia and Zimbabwe

(comprising the key Ministries involved in the social and economic sector) and Council of Ministers (Land Law Article 22 (3)) for approval.[2] Provisional DUATs are attributed for two years to foreigners and five years to nationals, after which definitive DUATs are allocated, subject to review by the government that production plans have been fulfilled.

5.3. Investment law

The basic legal framework for investment in Mozambique is established by Law No. 3/93 (the Investment Law of 1993). The Regulation, approved by Decree No. 14/93 in 1993 and subsequently altered by Decree No. 36/95 in 1995, defines the procedures for project evaluation. The government's Investment Promotion Centre (CPI) is responsible for implementing the legislation. All investment proposals have to be signed off by the Minister for Planning and Development, which oversees CPI.

Government approval of an investment project is necessary to gain access to certain fiscal benefits provided under the Code of Fiscal Benefits (Law No. 4/2009 of 12 January, 2009), which altered Decree No. 16/2002 of 27 June 2002, subsequent to the original Code of Fiscal Benefits approved by Decree No. 12/93 of 21 July 1993. The Code of Fiscal Benefits is expressed in a legal agreement between the government and the investor. It establishes incentives for investors to locate production in less-developed provinces. Two location-specific incentives are granted:

- Investment tax credits for five years are provided, equal to 5% of total realized investment in Maputo City province and 10% for other provinces. A greater distinction is made in relation to designated "rapid development zones", which are privy to a tax credit equivalent to 20% of total realized investment. These are geographical areas which have "great natural resource potential but which are lacking in infrastructure and have a weak level of economic activity" (Code of Fiscal Benefits). These include the Zambeze river valley, which covers all districts in Tete province, most districts in Zambézia and Sofala provinces and four districts in Manica province, Niassa province and Nacala district.
- Deduction of expenditure on infrastructure undertaken by the investor, equal to 110% of expenditure for projects located in Maputo City province and 120% of expenditure for projects in other provinces. No additional benefit is granted for the rapid development zones.

In September 2009, the government of Mozambique announced its plans to create special duty free industrial areas in the city of Nacala-Porto, Nampula province. The objective is to promote social and economic development of some provinces in the centre and north of the country, namely Zambézia, Tete, Niassa and Cabo Delgado (Macauhub, 2009c). This is most relevant for processing activities, which are heavily dependent on the use of imported goods and machinery.

5.4. Linking land and investment

Until recently, the process for evaluating land title requests and the evaluation of investment proposals linked to these requests were quite separate. The land title process concentrated mainly on the administrative steps laid down by the Land Law and its Regulation, while investment proposals were evaluated by CPI.

As a consequence of the increase in expressions of interest for large tracts of land, the government made two changes to the project review procedure. Firstly, it tightened the link between the processes for awarding land titles and approving investment proposals. Whereas previously a proposal for a large-scale investment project could be approved by the Council of Ministers independently of the land process, from 2007, investment and land-requests had to be submitted together to the Council of Ministers, with the two processes being launched simultaneously (Circular No. 009/DNTF/07 of 16 October 2007). In addition, the Provincial Governor had to submit an evaluation of both the land request and investment project.

Secondly, at the end of 2008, the Council of Ministers approved the introduction of Investment Guidelines (Resolution 70/2008). These are applied to large-scale projects, defined as more than 10,000 ha, establishing the type of information required for the presentation of projects to the Council of Ministers for their analysis. This now represents the legal basis for the evaluation of large-scale agrarian projects, including many of the biofuels projects submitted to the government.

5.5. National biofuel policy and strategy (NBPS)

On 21 May 2009 the Mozambican government published a national biofuels policy and strategy (Resolution 22/2009), partly based on a study on the technical, economic, social and environmental feasibility of biofuel production in Mozambique (Econergy, 2008). The Resolution, approved by the Council of Ministers, aims to contribute to energy security and sustainable socio-economic development by exploiting agro-energetic resources through stimulating the diversification of the energy matrix, contributing to the well-being of the population and promoting socio-economic development, particularly in rural areas (Government of Mozambique, 2009, 15).

The policy and strategy describes several measures intended to promote biofuel production while limiting potential negative impacts on society and the environment. Some of the important political and strategic pillars are: proposed limits on land allocation to biofuel production on the basis of suitable agro-climatic regions through land zoning; approval of selected feedstocks, namely sugarcane and sweet sorghum for ethanol, and coconut and Jatropha for biodiesel; the use of sustainability criteria to select investment projects and allocate land titles; the creation of a domestic market for biofuels via blending mandates, which will be gradually phased in at increasing levels; increase export to create tax-revenues and foreign currency; the promotion of regional markets for biofuels; and the establishment of tariffs for the purchase of electricity produced from biomass, particularly cogeneration of electricity as a by-product of the ethanol production process.

While the biofuels policy and strategy provides a general framework and guidelines for the development of the sector, further legislation in the form of Regulations will provide the necessary detail on the pricing mechanism for domestic sales of biofuels; the Biofuels Purchasing Programme, which will probably be based on an auctioning system; the level of fiscal incentives provided to the sector, in the form of substantial discounts on the existing fuel tax (TSC); the levels of blending mandates; and the level of tariffs to be established for cogenerated electricity produced from bagasse.

[2] Article 15 of the Regulation of the Investment Law. This article states that agricultural projects of over 5000 ha and forestry and livestock projects of over 10,000 ha should be submitted to the Council of Ministers. However, Article 22 (3) of the Land Law, which stipulates that requests for over 10,000 should go to the Council of Ministers seems to have taken precedence.

Table 1
Available land per province according to the agro-ecological zoning exercise, and estimated annual biomass production potentials.

Province	Agro-ecological zoning exercise (IIAM and DNTF, 2008)		Annual biomass production potential for 2015 based on Batidzirai et al. (2006, 61)	
	Total available land (ha)	% of total available land	Annual biomass production potentials (in PJ for 2015)	% of total biomass production potential
Zambézia	1,365,300	19.6	883	13.2
Niassa	1,220,400	17.5	1,176	17.6
Inhambane	1,071,660	15.4	113	1.7
Gaza	866,780	12.4	234	3.5
Nampula	709,160	10.2	1,144	17.2
Tete	661,730	9.5	576	8.6
Sofala	408,650	5.9	545	8.2
Manica	381,950	5.5	642	9.6
Cabo Delgado	269,400	3.9	1,286	19.3
Maputo	11,000	0.2	71	1.1
Total	6,966,030	100.0	6,670	100.0

The NBPS states that: "With modest expectations of biofuel expansion to 450,000 ha, combined with compulsory blending of E10 (10% of ethanol with 90% of gasoline) and B5 (5% of biodiesel with 95% of fossil diesel), the biofuel industry is expected to generate substantial macroeconomic benefits, including the reduction of oil imports and the creation of approximately 150,000 direct and indirect new jobs" (Government of Mozambique, 2009, 17–18).

6. Mozambique's biophysical potential

Mozambique has unexploited natural resources, favorable agricultural conditions and abundant labor that give it enormous economic potential for overcoming the present state of underdevelopment (Diao et al., 2007; Rebello Da Silva and Da Silva Garrilho, 2003, 65). The most recent exercise that summarizes Mozambique's biophysical potential on a national scale is the agro-ecological zoning carried out between October 2007 and May 2008. The zoning was coordinated by an inter-ministerial working group in which the National Institute of Agrarian Research (IIAM) identified the agro-climatic suitability of different areas, and the National Directorate for Land and Forestry (DNTF) assessed land availability. The zoning was carried out at a scale of 1:1,000,000, capturing contiguous areas of more than 1000 ha. Underpinning this exercise are a range of existing studies, including a national forestry inventory, soil and climate data and maps of agro-climatic suitability for different crops, including several potential biofuel feedstocks such as sugarcane and Jatropha. Land availability was determined by excluding existing DUATs (community or private), mining areas, projects submitted for approval, and projects 'in the pipeline'.

The land zoning exercise identified 6,966,030 million ha as being available for large-scale agricultural, forestry and livestock activities (IIAM and DNTF, 2008). Table 1 shows the distribution of available land per province (excluding Maputo City province).

Table 1 also includes work by Batidzirai et al. (2006) who studied Mozambique's annual biomass production potential for 2015 based on climate and soil characteristics. This study's main conclusion was that Mozambique has an estimated annual biomass production potential for 2015 of 6670 PJ using surplus land under moderate agricultural technological inputs.

While the land zoning exercise provided an important basis for guiding the government in its land allocation decisions, several concerns exist in relation to its reliability and usefulness:

- The current scale is too large to allow for more than a broad overview of land availability.
- Most of the soil suitability data were out-dated and analysis of agro-climatic suitability was based on rainfall data from the 1980 s.
- The zoning only considered water availability from rainfall, excluding opportunities for irrigated agriculture near rivers.

In addition, the accuracy of the land availability data has been called into question. A random locality in Mozambique identified as available based on 1 km^2 satellite databases turned out to be extensively utilized and inhabited when viewed at the finer resolution provided by Google Earth (Watson, 2008, 13).

A more accurate land zoning exercise is currently being carried out on a scale of 1:250,000.

7. Social and economic factors

This section describes and discusses the social and economic factors that influence biofuel developments in Mozambique. It focuses on the availability and quality of labor force, and access to infrastructure and services.

A rough indicator of potential labor force is population density per province. Mozambique has an average population density of 20.1 people per km^2 (WFP, 2009). In 2000, population rates per km^2 were highest for Nampula, Maputo and Zambézia provinces. Population density was lowest found in Niassa and Tete provinces (Table 2).

Quality of labor can be expressed in literacy rates, Net Enrolment Rates (NER), and achievement levels of formal education. According to the Mozambican Household Survey 2002–2003, adult literacy rates are around 50%[3]. There is evidence of large differences in literacy rates between rural households (27%) and urban households (66%) (Castanheira Bilale, 2007, 78). Manica, Maputo, and Maputo City province achieved much higher literacy levels than the national average while in most other provinces, adult literacy rates were below the average, with Cabo Delgado and Nampula at the lower end. In rural areas, on average 80.7% of adult residents did not have any formal education (Castanheira Bilale, 2007, 82). In Nampula, Zambézia, Cabo Delgado and Tete between 70% and 82% of the population had no formal education, and between 10% and 20% had only achieved primary education. Looking at current school enrolment figures (NER) we found that around 80% of children between 6 and 18 years of age are enrolled at school. The difference between

[3] HDI for 2007 indicated average literacy rates 44.4% for population above 15 years, but of this data specification per province was not available.

provinces was still present, with Maputo, Maputo City, Gaza, Inhambane and Manica provinces amongst the highest, and Nampula, Tete, Sofala, Cabo Delgado, Niassa and Zambézia provinces at the lower end (Table 2).

Portuguese colonization and armed conflicts destroyed and uprooted most of Mozambique's social and physical infrastructure (Arndt et al., 2000; Newitt, 1995, 570). Cooperatives and unions were systematically destroyed and service provision, such as access to agricultural inputs and extension, disappeared. Despite the sustained recovery since peace was reached in 1992 and efforts to improve infrastructure and distribution networks, access remains poor and patchy between provinces. In 2002, the highest level of communities with access to improved seeds, fertilizers and pesticides were found in Manica, Sofala and Inhambane provinces, while Tete was the lowest (TIA 2002 in Coughlin, 2006, 13). Access to extension services was low in every province with an average of 1.3 extension workers per 10,000 inhabitants (MADER 2004 in Coughlin, 2006, 32).

Despite recent investments in roads, the density of the road network is the lowest in southern Africa, at only 32 kilometers per km^2 (World Bank, 2006, xvi). "Under the Portuguese colonial government, roads and railways were mainly laid to facilitate the exportation of agricultural produce from Malawi, Zambia and Zimbabwe" (Coughlin, 2006, 6). The deep-sea ports of Maputo, Beira and Nacala are still used by Mozambique's neighboring countries to export and import a substantial part of their commodities (Meeuws, 2004, 5). These ports have (fuel) storage facilities and are well accessible by road. Poor north–south infrastructure makes transport by road inside the country more costly than exporting from the nearest port (cf. Coughlin, 2006, 6; World Bank, 2005, 60).

Efforts to provide electricity to rural Mozambique are mainly concentrated around urban centers, such as the Beira and Maputo corridors, and along the coast (OCIN, 2006). There are plans for building of a 1000 km north–south power line, linking hydro-electric, coal- and gas-fired power stations in central and northern Mozambique with the main consuming areas in the south (EarthTimes, 2009).

Table 2
Population density, literacy rates and Net Enrolment Rates (NER) per province.

Province	Population density (population per km^2) (CAP 1999–2000 quoted in: Coughlin, 2006, 6)	Literacy rates (Castanheira Bilale, 2007, 77) (%)	NER (Castanheira Bilale, 2007) (%)
Maputo City	Not included	77	93
Nampula	37.8	32	69
Maputo	35.6	67	94
Zambézia	28.1	40	77
Sofala	19.1	47	71
Cabo Delgado	16.4	28	72
Inhambane	16.4	52	86
Manica	15.6	60	84
Gaza	14.0	53	90
Tete	11.3	45	70
Niassa	6.2	49	74
Average for Mozambique	20.1	50	80

8. Reality of biofuel developments in Mozambique

This section presents an overview of the developments in the biofuel sector that have taken place in Mozambique since 2006, based on projects formally submitted to the Government of Mozambique, and an inventory of other implemented projects and expressions of interest. Given that individual investment proposals contain sensitive information, we have summarized the data in such a way that confidentiality is assured. Subsequently we have added an overview of the existing and planned biofuel-related infrastructure, such as processing and storage facilities.

We are aware that not all biofuel projects are actually being implemented at this stage. The objective of our inventory is therefore not to be speculative, but merely showing the areas where projects are being developed to provide a basis for further analysis of what is driving biofuel developments in Mozambique.

8.1. Formally submitted biofuel projects

Up to December 2008, the Government of Mozambique had officially received 17 biofuel-related investment proposals. Of these projects, 12 were related to biodiesel production and five to bioethanol production. The majority of investors originate in Europe or South Africa, often engaged in partnerships with Mozambican counterparts. The core business of nearly all biodiesel projects is growing Jatropha seeds to extract oil for the production of biodiesel. The bioethanol projects mainly focus on sugarcane as a feedstock, with some interest in sweet sorghum and cassava. Some of the projects have ancillary activities, such as production of seedlings or food production. The biodiesel investors requested 179,404 ha of land; the bioethanol investors 66,000 ha.

As Table 3 demonstrates, the proposed biodiesel projects amount to a total investment of US$298 million and the bioethanol projects US$1003 million. Average investment per hectare shows that sugarcane production is far more capital intensive than producing Jatropha, mainly driven by higher planting density, and costly investments in irrigation systems and ethanol distilleries. Total employment creation is expected to

Table 3
Analysis of the 17 biofuel investment proposals based on collaboration with CEPAGRI.

	Bioethanol projects		Biodiesel projects		Total
#	5	29%	12	71%	17
Land formally requested (ha)	66,000	27%	179,404	73%	245,404
Investment (US$)	1003 million	77%	298 million	23%	1301 million
Average investment per requested hectare (US$)	15,197		1663		5,303
Employment (jobs)	Between 8925 and 11,956	26–28%	Between 25,093 and 30,264	74–72%	Between 34,018 and 42,220
Employment per requested ha	Between 0.14 and 0.18		Between 0.14 and 0.17		Between 0.14 and 0.17
Main crop	Sugarcane		Jatropha		
Other crops	Sweet Sorghum, Cassava		–		
Estimated yields	113.3 t cane ha^{-1}		2.64 t Jatropha oil ha^{-1}		
Market	Mostly EU		Mostly EU		

be between 34,018 and 42,220 jobs. The available data shows that the biodiesel projects intend to create between 25,093 and 30,263 employment places (around 73% of total). The bioethanol projects account for between 8925 and 11,956 jobs (around 27% of the total) mainly depending on whether cane will be harvested manually or mechanically. Average employment per hectare does not differ much between the bioethanol and biodiesel sector. For the whole biofuel sector, the estimated employment potential is between 0.14 and 0.17 jobs ha^{-1}.

The 12 biodiesel projects aim at an average production of 2.64 t Jatropha oil ha^{-1} yr^{-1}. Research shows that yields depend highly on the growing conditions of the crop. Recent studies indicate a maximum of 2.72 t Jatropha oil ha^{-1} yr^{-1}, calculated on the basis of full radiation, high temperatures and year-round canopy cover, no limitations due to lack of water or nutrients, and the absence of plagues and diseases (Jongschaap et al., 2007, 28). Achieving these yields in practice will be extremely difficult, if not impossible.

The average expected yields by the three biggest sugarcane projects are 113.3 t cane ha^{-1}. By comparison, the best average yield for the Mozambican industry over the past five years was 72 t ha^{-1} and the best average company yield over the same period was 87 t ha^{-1} (CEPAGRI, 2009). Data from the Brazilian sugarcane sector shows averages of 77.6 t ha^{-1} in 2007 for dry-land cane (FAOSTAT, 2009).

Most projects intend to supply the domestic and regional (SADC) markets, as well as targeting the EU and broader international markets. However, since the EU has announced its renewable energy targets for 2020 (20% renewables, 10% blending of biofuels for the transport sector), the European market seems to be the premium market, where the highest prices will be paid. Most interviewed investors and experts confirm that initially: "Most of the ethanol produced in Mozambique will be exported to the EU" (Engineering News/Reuters, 2009).

Dropping fossil-fuel prices and the financial crises have had their impact on the biofuel sector in Mozambique. In 2009, only five biofuel-related investment proposals have been received, which is much lower as compared to the proposals received in 2008.

Table 4 shows the characteristics of the four formally approved biofuel projects (based on: Allafrica.com, 2007, 2009a; Engineering News/Reuters, 2009; Noticias August 21, 2009).

In October 2007, the first large-scale bioethanol project was formally approved. Procana Ltd., with a total investment of around US$500 million according to Allafrica.com (2007), is a Mozambican company in which the London-based Bioenergy Africa Ltd. is the main shareholder. Procana obtained a DUAT for 30,000 ha for irrigated sugarcane production southeast of Massingir (Gaza province). In July 2008, Principle Energy Ltd., also a London-based renewables energy company, was granted access to 18,000 ha in Dombe (Manica province). Like Procana, Principle Energy's main objective is to produce irrigated sugarcane for bioethanol production. Both projects intend to build on-site ethanol refineries where the sugarcane can be processed, and should generate between 7000 and 10,000 jobs, depending on whether cane is harvested manually or mechanically (Allafrica.com, 2009b).

On 6 October 2009 one of the major shareholders in Procana, Bioenergy Africa Ltd., announced a adaptation of investment policy and change of name. Based on a review of a 23 month period ending on 31 March 2009, the Directors believed that: "The global economic climate and current reduced interest in non-carbon related fuel products will make it difficult for the Company to raise the necessary financing required under the Massingir Investment Agreement" (BioEnergy Africa Ltd., 2009b). For the 23 month period under review, BioEnergy Africa is reporting a pre-tax loss of US$7.7 million (Bioenergy Africa Ltd, 2009a). The company intends to suspend further material investment in the Massingir Project. By the end of November 2009, the company's name and website had already been changed to Sable Mining Africa Ltd. In December 2009, the government voided the DUAT of Procana Ltd. because the company failed to comply with its contractual obligations (United Press International, 2009).

In August 2009, the Council of Ministers granted land titles to Enerterra SA and Grown Energy Zambeze Ltd., both in Sofala province. Enerterra SA is a company with Portuguese and Mozambican interests, which has been granted 18,920 ha for the production of Jatropha (Allafrica.com, 2009a). Grown Energy Zambeze Ltd., which has Mozambican, Asian and South African shareholders, has been granted 15,000 ha for the cultivation of sugarcane and sweet sorghum for ethanol production, and energy generation for the national grid. Grown Energy Zambeze is planning to construct an on-site ethanol distillery. In addition, beans and soya will be grown, in combination with livestock production. The project has budgeted a social fund of US$2.7 million to support education, health, infrastructure and electrification of the area (Noticias August 21, 2009).

While the 17 investments proposals aim at creating an average of between 0.14 and 0.17 jobs ha^{-1} (Table 3), the estimates of the four formally approved projects are slightly higher at an average of between 0.17 and 0.21 jobs ha^{-1}. This is however, still much lower compared to government projections of 150,000 new jobs for 450,000 ha (0.33 new jobs ha^{-1} including self-employment for entrepreneurs) (Government of Mozambique, 2009, 18).

Table 4
Analysis of the four formally approved biofuel projects.

	Principle Energy Ltd.	Procana Ltd.	Enerterra SA	Grown Energy Zambeze Ltd.	Total
Province	Manica	Gaza	Sofala	Sofala	
Land (ha)	18,000	30,000	18,920	15,000	81,920
Investment (US$ million)	290	500	53	212	1055
Investment per ha (US$)	16,111	16,667	2801	14,133	
Employment (seasonal)	Two projects should generate between 7000 and 10,000 jobs		5000		Between 14,163 and 17,163
Employment (permanent)			20	2104	
Mozambican			5	34	
Foreign			Total: 5025	Total: 2138	
Average jobs per ha	0.15–0.21		0.27	0.14	0.17–0.21
Main crop	Sugarcane	Sugarcane	Jatropha	Sugarcane	
Production (per year)	212 million litres of ethanol	298 million litres of ethanol	No data	100 million litres of ethanol	
Market	Mostly EU	Mostly EU	10% domestically/90% EU	10% domestically/90% EU, USA, Japan	

The other investment proposals are under consideration prior to potential approval, or are in the process of conducting baseline studies and Environmental and Social Impact Analysis. From interviews we know that one biodiesel project officially withdrew from the application procedure (this project, just like Procana is however included in our analysis of the investment data). We know that some projects are close to formal approval, others face difficulties getting their activities financed or are 'shelved'.

The fact that a project is not formally approved does not mean that no activities are being undertaken. Some of the projects have been granted land rights to start experiments and nurseries. However, fieldwork experiences showed us that some projects have already started bush-clearing, infrastructure, housing and plantation activities. We know of at least one biodiesel project that started operating on land rights transferred from another company. DUATs are transferrable, meaning that the name of the DUAT-holder and assets can be sold without effectively having to get a new DUAT. However, DUATs are linked to specific feedstocks and production plans, such that investors have to receive authorization from the government if land acquired in this way is intended for other use.

Reasons of confidentiality only allowed us to explicitly name the projects that have been formally approved in Fig. 2. The map contains 18 dots as one project intends to work at two different locations.

In Table 5 we compare land requested by the formally submitted proposals per province with the land availability per province as was identified through the 2008 agro-ecological zoning (scale 1:1,000,000). Except for Maputo province, the requests are still within the amount of land available per province. In total, investors requested for 3.5% of the total available land identified during the agro-ecological zoning of 2008.

As our analysis shows, the majority of available land can be found in the northern provinces of Mozambique; Zambézia, Niassa, Tete, Nampula and Cabo Delgado, representing 4,225,990 ha or 61% of the total available land. The central and southern provinces – Manica, Sofala, Inhambane, Gaza and Maputo – represent the remaining 2,740,040 ha or 39% of the total 6,966,030 ha. When looking at the formal land-requests by biofuel investors, we find the opposite: 63% or 154,436 ha of the total land requested is located in Manica, Sofala, Inhambane, Gaza and Maputo provinces, and the remaining 90,969 ha (37%) in Zambézia, Niassa, Tete, Nampula and Cabo Delgado provinces (Table 6).

8.2. Other implemented biofuel projects and expressions of interest

Besides the investment proposals that were formally submitted to the Mozambican government, a wide variety of other biofuel projects are being implemented and explored in Mozambique. These projects are very heterogeneous, ranging from large-scale commercial to smallholder development projects each with their own specific approach, objectives and markets.

Fig. 3 illustrates the geographical spread of the projects, distinguishing between bioethanol, biodiesel and projects producing Pure Plant Oil (PPO). The PPO-projects mainly focus on

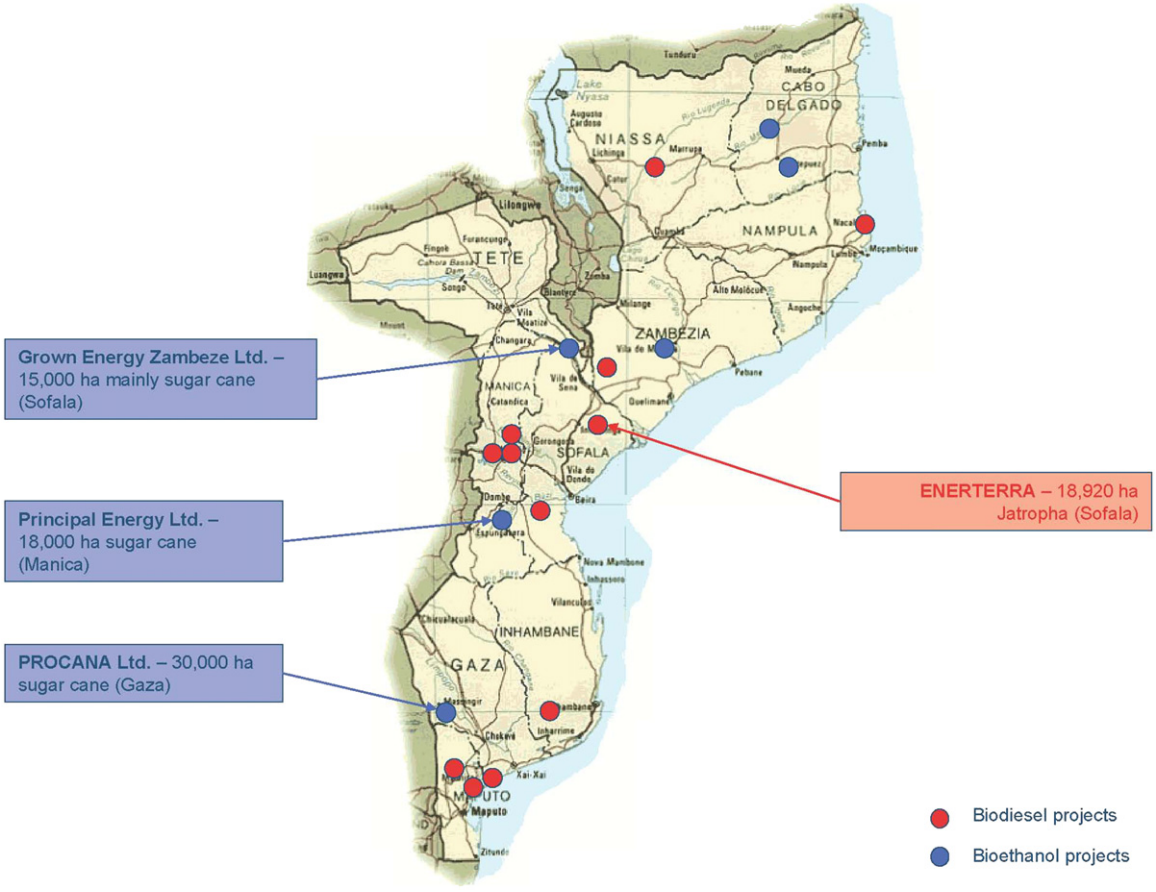

Fig. 2. Geographical spread of biofuel projects that formally submitted investment proposals to the Government of Mozambique, and the four biofuel projects that have been officially approved at national level.

Table 5
Land availability (agro-ecological zoning) versus land-request per province (17 formally submitted investment proposals).

Province	Agro-ecological zoning exercise (IIAM and DNTF, 2008)		Investment proposals formally submitted for approval to Government of Mozambique		
	Total land availability (ha)	% of total land available	Formal land-requests (ha)	% of total formal land requested	% of land requested compared to land availability (zoning)
Zambézia	1,365,300	19.6	72,618	30	5.3
Niassa	1,220,400	17.5	1,300	1	0.1
Inhambane	1,071,660	15.4	11,000	4	1.0
Gaza	866,780	12.4	30,138	12	3.5
Nampula	709,160	10.2	15,050	6	2.1
Tete	661,730	9.5	0	0	0.0
Sofala	408,650	5.9	43,920	18	10.7
Manica	381,950	5.5	57,122	23	15.0
Cabo Delgado	269,400	3.9	2,000	1	0.7
Maputo	11,000	0.2	12,256	5	111.4
Total	6,966,030	100.0	245,404	100	3.5

Table 6
Land requested compared to land availability per region.

Provinces	Agro-ecological land zoning (IIAM and DNTF, 2008)		Investment proposals formally submitted to Government of Mozambique	
	Land identified as available (ha)	% of total land available	Requested land (ha)	% of total land requested
Maputo, Gaza, Inhambane, Manica and Sofala	2,740,040	39	154,436	63
Tete, Niassa, Cabo Delgado, Zambézia and Nampula	4,225,990	61	90,968	37
Total	6,966,030		245,404	

producing Jatropha oil by smallholders for local energy use. The success of these smallholder projects ranges enormously. Where some projects are already harvesting, collecting, and pressing Jatropha seeds, other initiatives have been abandoned by farmers due to bad performing Jatropha and lack of agronomic management skills on how to prune, control pests and viruses (Bos et al., 2010).

In line with the formally submitted projects, Fig. 3 demonstrates a concentration of biofuel activities in the Beira-corridor, around Quelimane and along the southern coast between Maputo and Inhambane. The majority of projects focus on Jatropha as feedstock, either to produce PPO or biodiesel as end-product.

8.3. Existing and planned processing and storage facilities

Mozambique currently has four operating sugar mills; Marromeu and Mafambisse sugar mills (Sofala province), and Xinavane and Maragra sugar mills (Maputo province). None of these sugar mills are currently producing ethanol, but by showing their location, we seek to indicate which areas potentially provide access to goods and services related to the emerging biofuel sector in Mozambique. One of the sugar producers – Tongaat-Hulett (with shareholding in Mafambisse and Xinavane sugar estates and mills) – recently expressed their intention to move into the bioethanol market over the next few years, requiring a mandatory 10% blending regime to kick-start renewable energy programs (BusinessReport, 2009). There is one operating distillery in Mozambique in the Búzi region about 50 km from the Beira port. This distillery, with installed capacity of 3 million l yr^{-1}, produces alcohol for beverages and pharmaceutical applications using molasses as a feedstock (Econergy, 2008, 192).

While no biodiesel was produced prior to 2006, Mozambique produces oilseeds and has a small vegetable oil industry. The domestic oilseeds industry is composed of small- and medium-sized companies whose production is monitored by the Ministry of Industry and Commerce (MIC) (Econergy, 2008, 130). Eight oil production facilities are registered with the MIC. In general, refined oil is processed from raw copra oil. Raw copra oil has two markets: the domestic soap industry, and export, primarily to South Africa for the cosmetics industry (Econergy, 2008, 130). The domestic oil refining industry relies heavily on imported oils to supplement domestic supply.

There exists an embryonic biodiesel sector in Mozambique, using coconut oil, and occasionally palm oil as feedstock (Econergy, 2008, 131–132). As the prices of coconut oil went up significantly, the opportunity cost of using the oil for biodiesel rather than sale on the international market was too high. The most prominent biodiesel project is Ecomoz, in which Mozambique's oil company PetroMoc has a 30% share. Ecomoz started operating in 2007, mainly using coconut oil as feedstock. The product is refined in Matola, Maputo province. The refinery has a capacity of 100,000 l day^{-1}, but limited quantity and quality of feedstock is preventing this potential from being achieved. Currently, Ecomoz sells its biodiesel to PetroMoc, using it in their company's cars while awaiting approval of the blending license to sell to the market. Ecomoz is planning to expand production and use 21,000 ha in Manhiça district to produce Jatropha and copra (PetroMoc, 2009) (Fig. 4).

Besides the existing facilities, the Mozambican government is rehabilitating, expanding and modernizing three PetroMoc storage facilities in Nacala, Beira and Maputo. A new facility of 95,000 m^3 is constructed in Beira. Storage facilities which are in study are located in Vandúzi Manica, Beira and Maputo/Porto de Dobela (PetroMoc, 2009). These units are not specifically designed for biofuels but aim to be versatile and accommodate normal fossil-fuel, gas, biofuels and all kind of liquid fuels that will be necessary (personal communication PetroMoc).

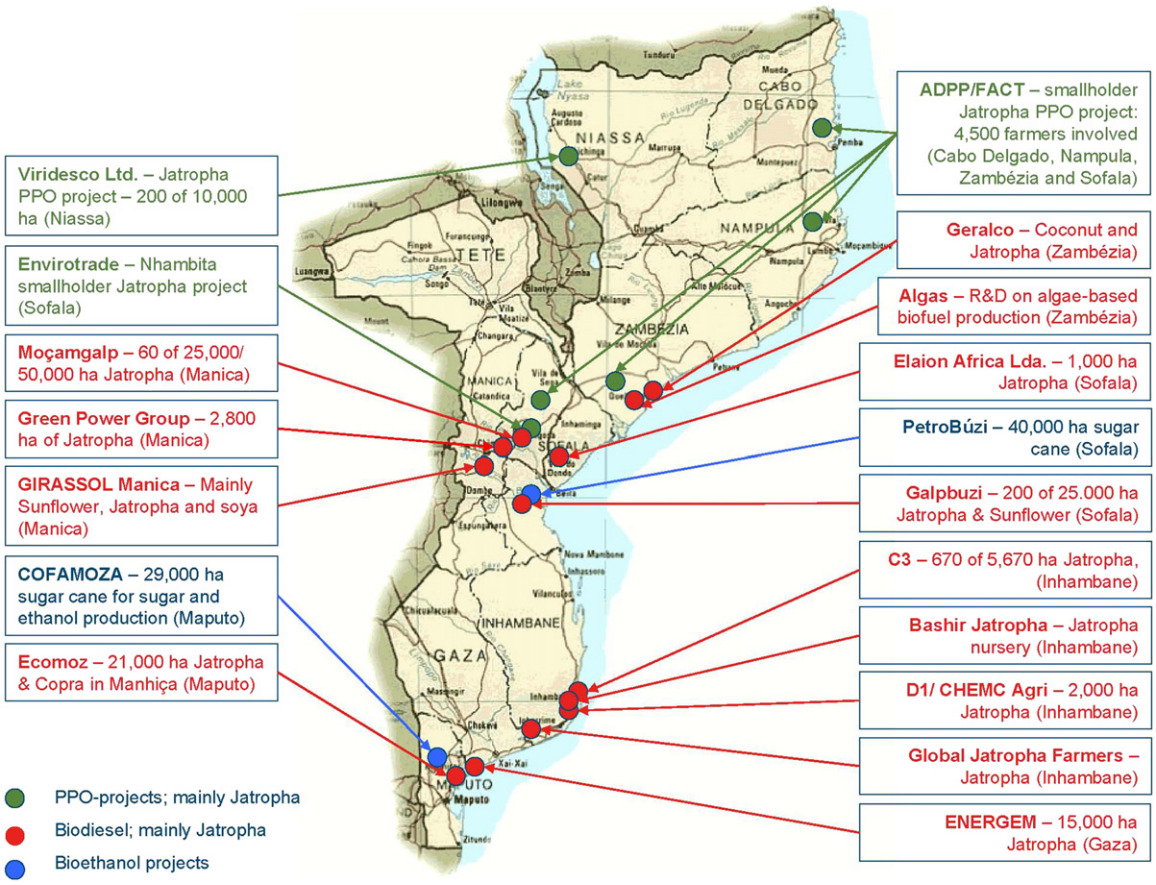

Fig. 3. Geographical spread of other implemented biofuel projects and expressions of interest.

Galpbuzi, a consortium made up of Mozambican company *Companhia do Búzi* and Portugal's Galp Energia presented its long term plans to set up a biofuel refinery in the town of Búzi, in Sofala province. Mentioning that the project needed an area of 8000 ha, the General Manager explained they are planning to invest US$140,000, with part of production expected to be exported and the remainder used for domestic consumption (Macauhub, 2009a). British company Sun Biofuels also announced the construction of a factory to refine biodiesel from Jatropha near Chimoio in Manica province aiming at producing around 20,000 l of biodiesel per year (Macauhub, 2009b). Petrobuzi (PetroMoc) intends to construct an on-site ethanol distillery (CPI, 2009), just like Procana, Principle Energy and Grown Energy Zambeze. As Procana's contract was recently voided by the government, it is unclear if this facility will be constructed.

Fig. 5 presents the location of planned processing and storage facilities. According to our inventory, there is a strong concentration of planned processing and storage facilities around Beira. It must be noted that many issues related to feedstock quantity, economic sustainability and administrative procedures have to be resolved before individual projects can justify establishing processing and storage facilities.

8.4. Overview of biofuel developments in Mozambique

Fig. 6 brings together all implemented biofuel projects and expressions of interest. We added existing and planned biofuel-related processing and storage facilities, and indicated the concentration of activities. It shows that the highest concentration of biofuel activities can be found around Maputo up to Inhambane, and in and around the Beira-Corridor, followed by the south of Zambézia province around Quelimane and the north of Nampula province and the south of Cabo Delgado province.

Table 7 summarizes the inventory of formally submitted proposals, other implemented biofuel projects, expressions of interest, and existing and planned biofuel-related processing and storage facilities per Mozambican province.

As Table 7 demonstrates, 71% of biofuel projects (formally submitted and other projects) are located in Maputo, Gaza Inhambane, Sofala and Manica provinces. The remaining 29% of biofuel projects are located in Zambézia, Niassa, Nampula and Cabo Delgado provinces.

Of the existing and planned processing and storage facilities, 90% are located in Maputo, Manica and Sofala provinces. There appears to be a relation between the location of processing and storage facilities and the geographical interest of the projects, as 50% of the implemented biofuel projects and expressions of interest are also located in these provinces. We believe that biofuel projects prefer locations near processing and storage facilities, mainly because this will reduce transport costs.

When combining the geographical data on implemented projects and expressions of interest with data on existing and planned processing and storage facilities, the differences between North and South Mozambique become even more evident: 80% of the total biofuel developments are in Maputo, Gaza and Inhambane, Sofala and Manica provinces, and only 20% in Zambézia, Niassa, Nampula and Cabo Delgado provinces. Tete is the only province where no biofuel developments take place.

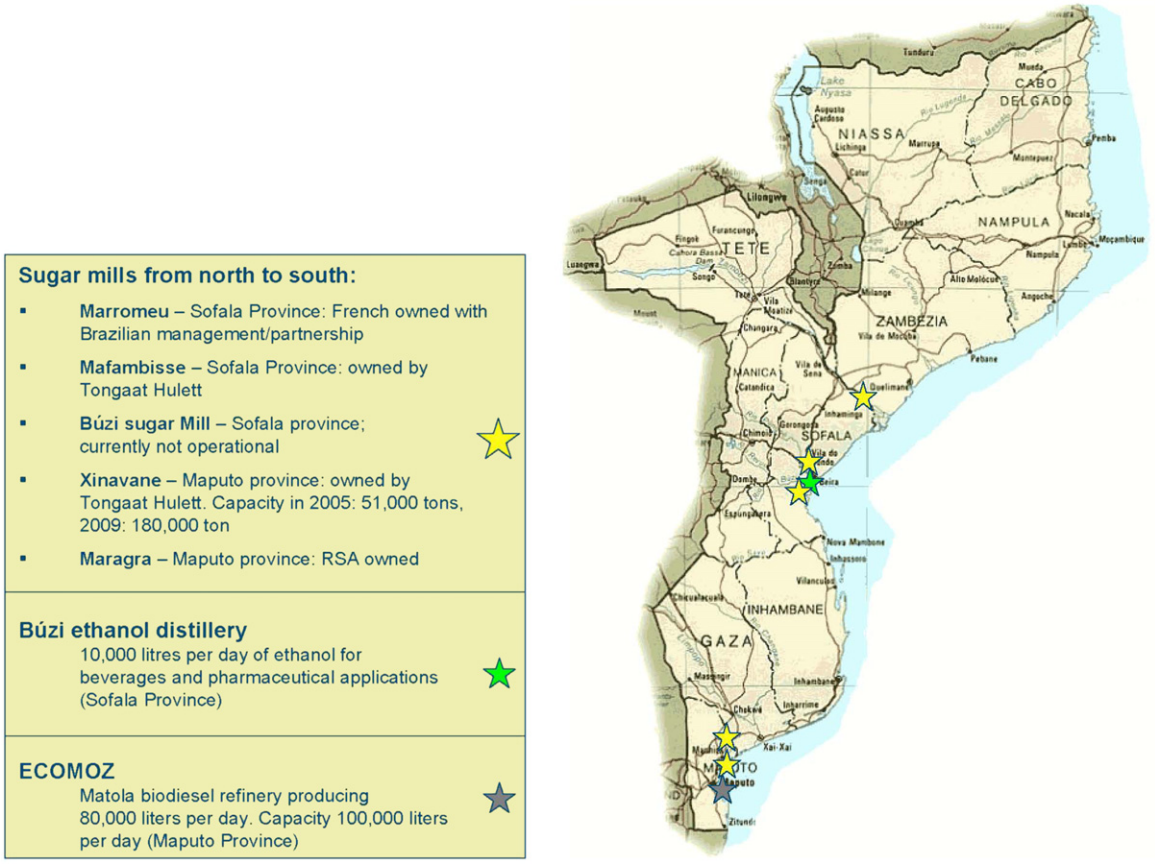

Fig. 4. Locations of existing biofuel-related processing facilities.

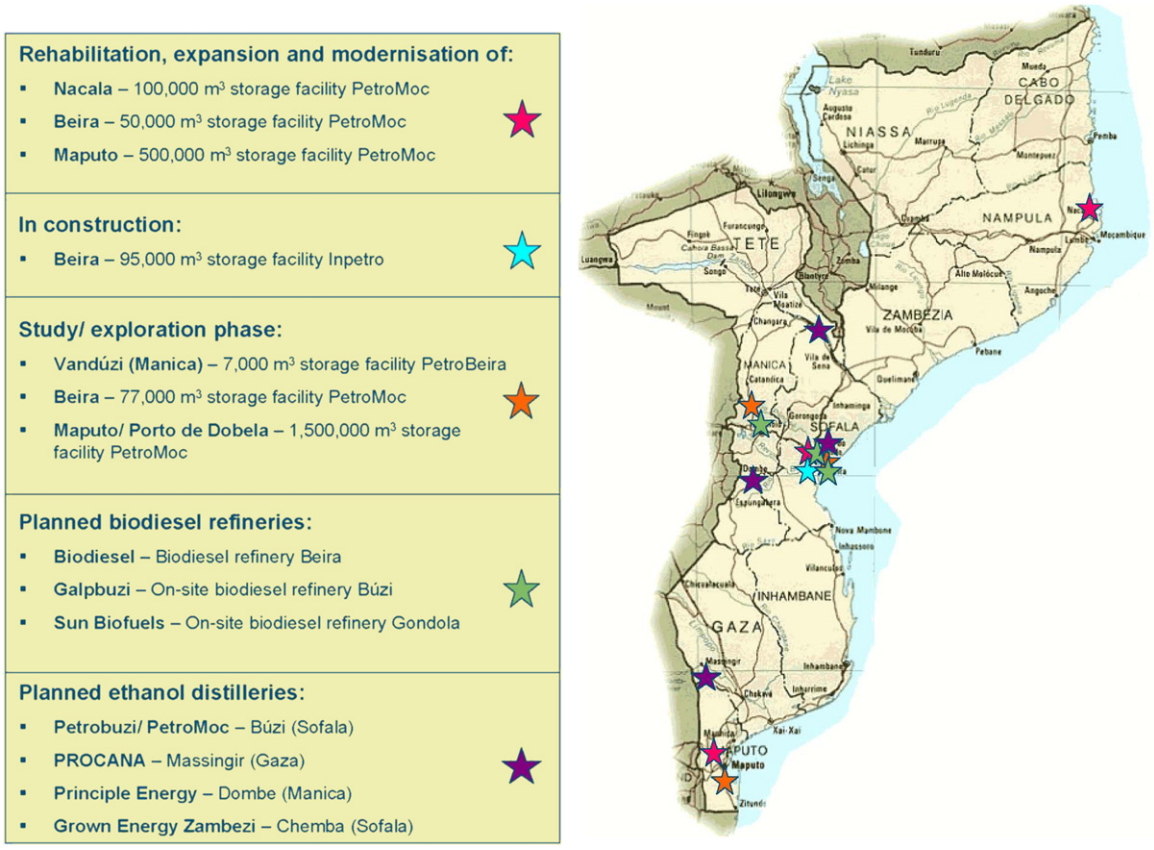

Fig. 5. Location of existing and planned processing and storage facilities.

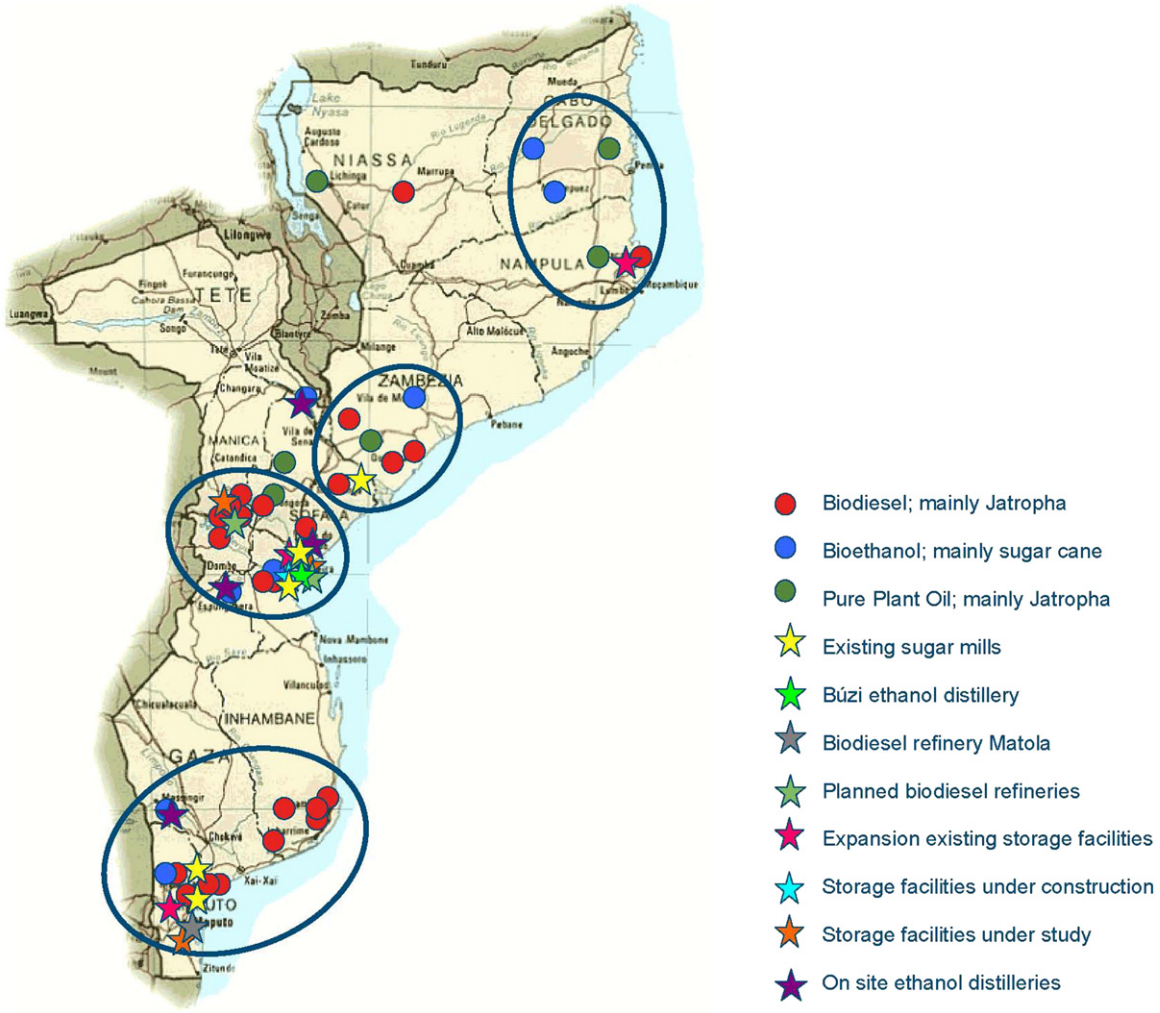

Fig. 6. Geographical spread of biofuel developments in Mozambique.

Table 7
Analysis of biofuel developments per Mozambican province.

	Bioethanol projects				Biodiesel and PPO-projects				Total projects		Processing and storage facilities		Total	
Province	# Formal	# Other	# Total	%	# Formal	# Other	# Total	%	#	%	# Total	%	#	%
Maputo	0	1	1	14	2	1	3	10	4	11	5	24	9	15.3
Gaza	1	0	1	14	1	1	2	6	3	8	1	5	4	6.8
Inhambane	0	0	0	0	1	4	5	16	5	13	0	0	5	8.5
Sofala	1	1	2	29	2	4	6	19	8	21	11	52	19	32.2
Manica	1	0	1	14	3	3	6	19	7	18	3	14	10	16.9
Tete	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
Zambézia	1	0	1	14	1	3	4	13	5	13	0	0	5	8.5
Niassa	0	0	0	0	1	1	2	6	2	5	0	0	2	3.4
Nampula	0	0	0	0	1	1	2	6	2	5	1	5	3	5.1
Cabo Delgado	1	0	1	14	0	1	1	3	2	5	0	0	2	3.4
Total	5	2	7	100	12	19	31	100	38	100	21	100	59	100

9. Drivers of biofuel developments in Mozambique

The objective of this paper was to analyze knowledge from different disciplines to provide an overview of current biofuel developments in Mozambique, exploring to what extent reality matches the country's biophysical potential and government's objectives as described in the NBPS. In our analysis, we have tried to highlight what appear to be the key drivers behind biofuel developments in the country.

9.1. Policy drivers

The majority of implemented and planned biofuel projects are outside the areas defined as 'Rapid Development Zones', which are located in regions with poor infrastructure and low levels of human capital. This may reflect the fact that the incentives provided under the Investment Law and Code of Fiscal Benefits consist mainly of reduced payment of corporate taxes once profits have been made, while it is more difficult to make profits in areas

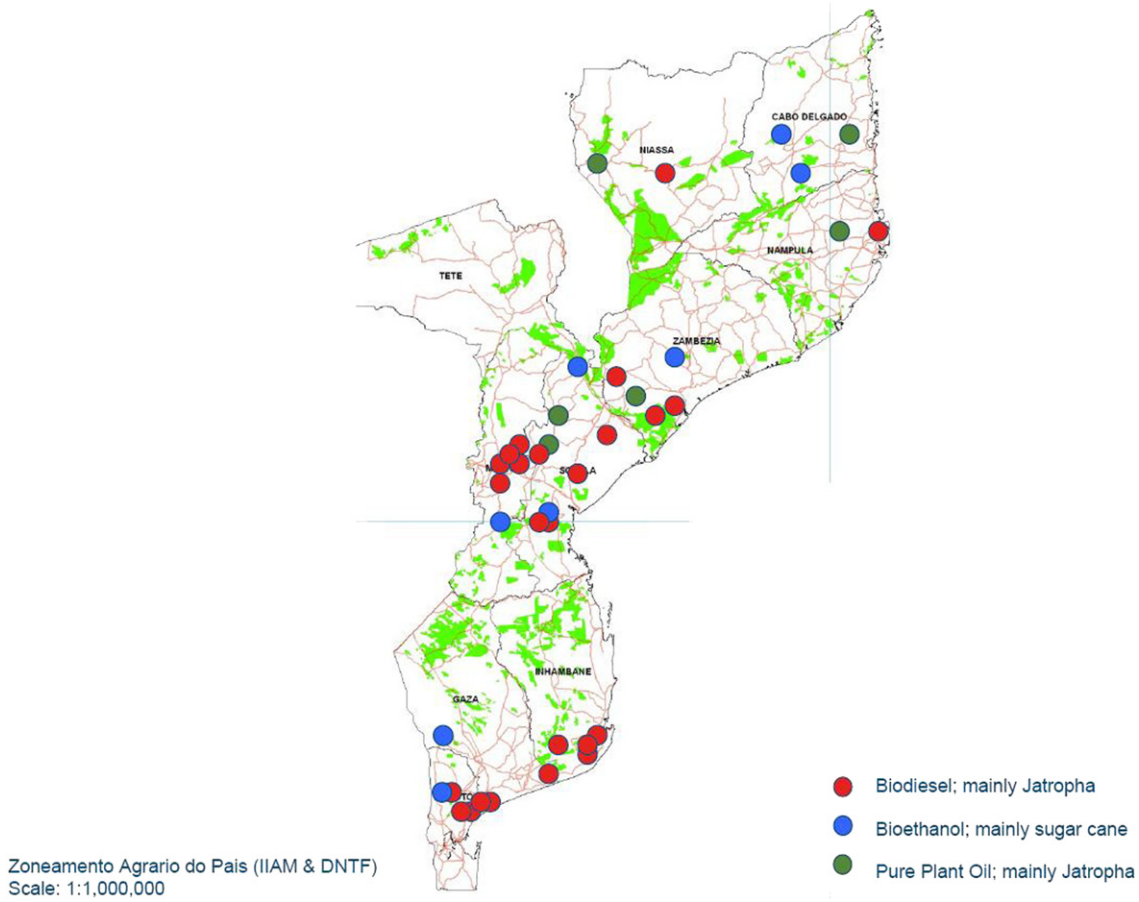

Fig. 7. Geographical spread of implemented projects and expressions of interest versus agro-ecological zoning in Mozambique (IIAM and DNTF, 2008).

which are far from major target markets and poorly serviced by basic infrastructure.

The creation of special duty free industrial areas near big cities (like Nacala-Porto, Nampula's deep-sea port) might stimulate the agglomeration effect (Wheeler and Mody, 1992). The concentration of biofuel industry in such areas make them increasingly attractive for future biofuel feedstock producers, as these areas provide the necessary infrastructure, access to goods, services and expertise and allow feedstock producers to keep transportation costs low.

In relation to market selection, it is too early to comment conclusively as the NBPS was only recently put in place. Although the government identified establishing the domestic market as priority, blending mandates will take some time to put in place, and other policy instruments designed to create domestic demand are not yet defined. As SADC and other regional markets for trading biofuels are also to be established, investors focus on the EU market where incentives are already in place, such as premium prices and tariff advantages under trade agreements.

9.2. Biophysical potential

The general scale of the land zoning exercise (1:1,000,000) does not allow us to draw very firm conclusions about whether or not projects are located in areas where land is most available. However, we can observe that the provinces with highest interest for biofuel projects[4] (71% of the projects are located in Maputo, Gaza, Inhambane, Manica and Sofala) only represent 39% of land available. The rest of the projects (29%) are spread over the northern provinces that represent 61% of the available land (Fig. 7).

This difference becomes even more visible if we zoom in on Maputo, Manica and Sofala provinces. 50% of the biofuel projects are located in these provinces, whereas they only represent 11.6% of the 6,966,030 ha identified as available during the zoning. Maputo, for example, only has 11,000 ha of land available, whereas 12,256 ha (111.4%) was requested by investors.

We can draw a similar conclusion if we compare our findings with the projection of provincial biomass annual production potential for 2015 based on climate and soil characteristics (Batidzirai et al., 2006, 61–62). We see that 32% of the biofuel projects are located in Maputo, Gaza and Inhambane provinces, whereas these provinces only represent 6.3% of the country's 6670 PJ total annual biomass production potential (see Table 1). Provinces with highest annual biomass production potential such as Niassa, Cabo Delgado and Nampula (54.1% of total annual biomass production potential), are not very popular among investors, as only 16% of the biofuel projects have interest in locating themselves in these provinces. This is likely to be explained by the almost total absence of infrastructure, and the lack of (skilled) labor in these provinces.

9.3. Socio-economic factors

Our analysis revealed an apparent relationship between the spatial availability of (skilled) labor, access to inputs, the availability and quality of infrastructure (roads and ports), and

[4] *Note*: If we refer to 'biofuel projects', this does not include the existing and planned processing and storage facilities

the number of biofuel projects in these areas. Provinces with a combination of low population density, low literacy levels and low net school enrolment rates (NER) such as Tete, Niassa, Nampula and Cabo Delgado were not attractive for biofuel projects. Provinces with relative high population density, highest adult literacy rates and NER such as Maputo, Inhambane and Manica coincided with a high number of implemented and planned biofuel projects. On the contrary, Sofala province does not score very well on population density, literacy levels and NER, but has the highest number of implemented and planned biofuel projects in the country. This high interest in Sofala could be explained by relatively good access to agricultural inputs, existing and planned processing and storage facilities, electricity and infrastructure such as Beira port.

In general, we saw a high concentration of biofuel projects around areas with good infrastructure and access to ports, such as Maputo, Beira, Quelimane, Nacala and Pemba, where existing fuel storage facilities are also present. This is rational, as a significant quantity of biofuels produced in Mozambique will be used to supply external markets.

10. Conclusions

Since the initial promotion of biofuels in 2004, much has changed in Mozambique. From promoting biofuel production by smallholders for domestic purposes, the sector is currently dominated by foreign commercial investors whose main intention is supplying external markets.

Based on our analysis and geographical mapping, we can conclude that biofuel developments mainly take place in areas near good infrastructure (roads and ports), where there is (skilled) labor available, and access to services and goods, processing and storage facilities; not deviating from the classical variables from investment theory. We also found that current developments appear to be less driven by biophysical potential and incentives provided within prevalent government policy.

As compared to the policy objectives described in the NBPS, our analysis shows that currently only few projects are located in remote, rural areas. Moreover, job creation as proposed by investors seems lower than expected by the government in the NBPS. Nonetheless, although the currently operational biofuel projects are not in the most remote rural areas, they do contribute to socio-economic development by generating employment, income and more indirect local spin-offs. Most investors – in absence of domestic or regional markets – focus on supplying external markets. Although this is in line with the NBPS to generate tax-revenues and foreign currency, it does not contribute to diversifying the country's energy matrix, or decreasing the fossil-fuel dependency Mozambique is facing.

It will be important for the Mozambican government to closely monitor developments in the biofuel sector, to understand the dynamics at play that are driving the direction of biofuel developments, and how these can harmonized with the country's NBPS-objectives. This requires the timely development and implementation of adequate policy tools and instruments to increase the likelihood that biofuel developments in Mozambique will enable the country to benefit its potential.

Lastly we would like to mention that the maps, tables and figures that we used to visualize our findings were extremely useful when sharing our results with policy-makers and other stakeholders. Notably the maps served as tangible boundary objects to which different communities of actors could easily relate (cf. Klerkx et al., 2010). This helped us to position the outcome of this research in the biofuel policy debate.

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References

African Development Bank, 2008. Mozambique Private Sector Country Profile. African Development Bank, p. 23.
Allafrica.com, 2007. Mozambique: Contract Signed for Ethanol Production.
Allafrica.com, 2009a. Mozambique: Government Approves New Projects for Biofuels, Maputo.
Allafrica.com, 2009b. Mozambique: Investments in Ethanol Production.
Arndt, C., Benfica, R., Maximiano, N., Nucifora, A.M.D., Thurlow, J.T., 2008a. Higher Fuel and Food Prices: Economic Impacts and Responses for Mozambique. IFPRI, p. 24.
Arndt, C., Benfica, R., Tarp, R., Thurlow, J., Uaiene, R., 2008b. Biofuels, Poverty and Growth: A Computable General Equilibrium Analysis of Mozambique. IFPRI p. 17.
Arndt, C., Jensen, H.T., Tarp, F., 2000. Stabilization and structural adjustment in Mozambique: an appraisal. Journal of International Development 12, 299–323.
Batidzirai, B., Faaij, A.P.C., Smeets, E., 2006. Biomass and bioenergy supply from Mozambique. Energy for Sustainable Development X, 54–81.
Bioenergy Africa Ltd, 2009a. Final Results. BioEnergy Africa Limited, p. 17.
BioEnergy Africa Ltd, 2009b. Proposed Adoption of Investing Policy and Change of Name. BioEnergy Africa Limited, p. 4.
Bos, S., Leonardo, W., Lerner, A., Schut, M.L.W., 2010. Assessing the potential of bioenergy production in smallholder farming systems: the case of Nhambita community. GTZ-ProBEC and Wageningen University and Research Centre, Maputo, p. 47.
BusinessReport, 2009. Tongaat Hulett to turn sugar cane into renewable energy.
Castanheira Bilale, F.J., 2007. Educational performance in Mozambique: an economic perspective. Department of Economics, University of Stellenbosch, p. 168.
CEPAGRI, 2009. Balanço do plano económico e social de 2008. CEPAGRI, Maputo, p. 278.
Commission of the European Communities, 2006. An EU Strategy for Biofuels.
Coughlin, P.E., 2006. Agricultural Intensification in Mozambique: Infrastructure, Policy and Institutional Framework. EconPolicy Research Group, Lda. p. 78.
CPI, 2009. Invest in Mozambique. US Trade and Investment Conference, Maputo.
Davidson, W.H., 1980. The location of foreign direct investment activity: country characteristics and experience effects. Journal of International Business Studies 11, 9–22.
De Matteis, A., De Oliveira, L., Martell, P., Correia, J.S., 2006. Baseline Survey of Food Security and Nutrition in Mozambique. Technical Secretariat for Food Security and Nutrition: Vulnerability Analysis Group, Maputo.
Diao, X., Hazall, P., Resnick, D., Thurlow, J., 2007. The Role of Agriculture in Pro-Poor Growth in Sub-Saharan Africa. IFPRI, Washington, DC.
Diaz-Chavez, R., Jamieson, C., 2008. South African Case study for RFA review of indirect effects of biofuels. Renewable Fuels Agency.
EarthTimes, 2009. Brazil to invest 300 million dollars in Mozambique infrastructure.
Econergy, 2008. Mozambique Biofuels Assessment. Ministry of Agriculture of Mozambique, Ministry of Energy of Mozambique, p. 426.
Embassy of the United States, 2006. Country Commercial Guide 2006. Trade Regulations and Standards, Maputo, Mozambique (Chapter 5).
Engineering News/Reuters, 2009. Investment worth $710 m flows into Mozambique ethanol projects.
Ewenstein, B., Whyte, J., 2009. Knowledge practices in design: the role of visual representations as 'Epistemic objects'. Organization Studies 30 (1), 7–30.
FAO, 2007. Mozambique Fact Sheet. FAO Emergency and Rehabilitation Programme in Mozambique, p. 2.
FAO, 2008a. Soaring food prices: facts, perspectives, impacts and actions required. In: Proceedings of the High-Level Conference on World Food Security: The Challenges of Climate Change and Bioenergy, Rome, Italy.

FAO, 2008b. The state of food and agriculture: Biofuels: Prospects, Risks and Opportunities. FAO, Rome, Italy, p. 128.
FAOSTAT, 2009. Yields per hectare Brazilian sugarcane industry.
Frontier Markets, 2008. Africa's biofuel boom: Mozambique.
Government of Mozambique, 2009. Política e Estratégia de Biocombustíveis, p. 9.
IIAM and DNTF, 2008. Zoneamento Agrário—Resultados do exercício de validação de validação de resultados de terra disponível a nível local (fase 2). IIAM and DNTF, Maputo, p. 16.
Jongschaap, R.E.E., Corré, W.J., Bindraban, P.S., Brandenburg, W.A., 2007. Claims and facts on *Jatropha curcas* L.: global Jatropha curcas evaluation. breeding and propagation programme. Report/Plant Research International, 158. Plant Research International, Wageningen.
Jumbe, C.B.L., Msiska, F.B.M., Madjera, M., 2009. Biofuels development in Sub-Saharan Africa: are the policies conducive? Energy Policy 37, 4980–4986.
Klerkx, L., Aarts, N., Leeuwis, C., 2010. Adaptive management in agricultural innovation systems: The interactions between innovation networks and their environment. Agricultural Systems, in press.
Macauhub, 2009a. Bio-Fuel Refinery Project in Sofala.
Macauhub, 2009b. Britain's Sun Biofuels designs biofuel factory to be installed in Manica province, Mozambique, Maputo.
Macauhub, 2009c. Mozambique to create special duty free areas in Nacala.
Meeuws, R., 2004. Mozambique: Trade and Transport Facilitation Audit. NEA Transport Research and Training, Rijswijk, The Netherlands, p. 91.
Newitt, M., 1995. A History of Mozambique. Indiana University Press, Bloomington and Indianapolis.
Noticias, August 21 2009. Grown Energy investe na produção de bioetanol. Noticias, Maputo, p. 2.
OCIN, 2006. Mozambique Electricity IV. Project Appraisal Report. African Development Fund.
PARPA II, 2006. Action Plan for the Reduction of Absolute Poverty 2006–2009. UN Mozambique.
PetroMoc, 2009. Biocombustíveis, PABO—Powering Africa: The Biofuels Options. Maputo, Mozambique.
Rebello Da Silva, G., Da Silva Garrilho, L., 2003. Bridging the standards divide; a case study and action plan for Mozambique. In: Wilson, J.S., Abiola, V.O. (Eds.), Standards & Global Trade; A Voice for Africa. The World Bank, Washington, D.C, pp. 65–164.
Smeets, E.M.W., Faaij, A.P.C., Lewandowski, I.M., Turkenburg, W.C., 2007. A bottom-up assessment and review of global bio-energy potentials to 2050. Progress in Energy and Combustion Science 33, 56–106.
TechnoServe and ICRAF/IIAM, 2006. Jatropha Plan. Jatropha Research and Development Team, Maputo, p. 11.
UNDP, 2009. Human Development Report 2009 Mozambique.
United Press International, 2009. Mozambique voids biofuel contract.
USAID, 2009a. Food Security Framework—Underlying Factors.
USAID, 2009b. Mozambique. USAID, Maputo, Mozambique.
van Dam, J., Junginger, M., Faaij, A., Jürgens, I., Best, G., Fritsche, U., 2008. Overview of recent developments in sustainable biomass certification. Biomass and Bioenergy 32, 749–780.
Watson, H., 2008. Biofuels in Africa – The Land Use Issue, Bioenergy Policies for Sustainable Development in Africa. Hotel Olympe International, Bamako, Mali.
WFP, 2009. World Food Programme Country brief on Mozambique.
Wheeler, D., Mody, A., 1992. International investment location decisions: the case of U.S. firms. Journal of International Economics 33, 57–76.
World Bank, 2005. Mozambique: Country Economic Memorandum Sustaining Growth and Reducing Poverty. World Bank, Poverty Reduction and Economic Management I, Africa Region.
World Bank, 2006. Mozambique Agricultural Development Strategy: Stimulating Smallholder Agricultural Growth. Worldbank: Agriculture, Environment, and Social Development Unit, Country Department 2, Africa Region.
World Bank, 2008. Mozambique at a glance.
World Bank, 2009. Mozambique—Country Brief.