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Options for suitable biofuel farming

Experience from Southern Africa

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Abstract: Southern African countries' interest in biofuel is due of its rural development potential. Finding models to optimize this benefit is therefore paramount. High-energy-density crops with low perishability allow farmers to grow small quantities on existing lands. Highly perishable, low-density crops such as sugarcane require tight integration between growers and mills. Models where growers have full ownership in the feedstock production facilities are possible, but this normally means that smallholder farmers need to work as a unit to achieve benefits of scale. Finding market-based mechanisms to ensure sound and equitable returns for land and labour inputs is critical.

Keywords: biofuel, jatropha, sugarcane, rural development, ethanol, Southern Africa
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1 Introduction

Biofuels have been promoted as a major development opportunity for Southern Africa (Gasparatos et al. 2015; World Bank 2011). As far as we can ascertain, all Southern African countries with the exception of Lesotho have initiated a process of identifying possible biofuel projects. This process was initially investor-led, with foreign investors requesting land for biofuel development before any of the Southern African countries had a suitable policy framework in place (Haywood et al. 2008). In response, the countries started developing local biofuel strategies, mandates, and legislation around biofuel projects and local conditions under which they could be initiated.

The initial biofuel boom in the region appears to have been largely stimulated by the European Union's Renewable Energy Directive (RED). Investors anticipated a huge and lucrative EU market and started investigating opportunities to meet this demand. This stimulated a large interest in land acquisitions in Africa, much of this as foreign direct investment (FDI) acquisition of large blocks of land on which to establish large commercial biofuel plantations. Some projects, however, focused on smallholder-based production models. African biofuel was initially geared more toward export opportunities and less toward local or regional fuel markets. However, the RED 'pull' for international biofuels seems to have been overestimated. African governments also realized that there might be more benefit to be gained from local use of biofuel, which would offset imports of fossil fuel. The African governments' priorities around biofuels have also tended to have a far stronger developmental than environmental focus (von Maltitz and Stafford 2011). It is therefore important that African countries consider the best management options for biofuels so as to best achieve their national interests.

Biofuel projects in the region tended to focus on two main feedstocks. Jatropha, a shrub with oil-bearing but toxic seeds, was the crop around which a large proportion of projects were initially based. Numerous jatropha projects were initiated (von Maltitz and Setzkorn 2013), though very few were fully implemented (von Maltitz et al. 2014). The second crop that received a lot of attention was sugarcane. Despite much talk, to the best of our knowledge no projects are yet operational. Malawi, however, has a sugarcane-based ethanol project that has been operational since 1982. Furthermore, sugarcane for sugar production is a well established crop in the region, with projects operational in South Africa, Swaziland, Mozambique, Zambia, and Zimbabwe.

Biofuel feedstock, within developing countries, is typically grown in one of two farming models, often in combination with each other:

- As large commercially run plantations
- By small-scale farmers in what is often termed an outgrower model.

Although this is a simple and very useful differentiation, the differences between the two approaches, with the exception of some nuances, are diminishing in some of the newer models.

This paper will consider some of the farming models being used in the region and discuss positive and negative aspects of the different models. No single model can be considered as perfect, and while different models are better suited to different situations, a set of principles can be developed to improve in particular the equity aspects of feedstock farming.

2 Methodology

Case studies from the Southern African region are used to better understand a number of benefits and trade-offs related to biofuel expansion. Since there are few active biofuel projects, experience in the sugar industry where sugarcane is grown was also investigated. Data were obtained from detailed case studies undertaken previously by the author. Further data were gathered from a wide selection of Southern African sugar projects using key informant interviews. Secondary data were gathered from key stakeholders in the sugar industry and from the literature. Four detailed case studies are the Niqel jatropha plantation in Mozambique, Dwangwa sugar in Malawi, BERL jatropha in Malawi, and SWADE sugarcane in Swaziland. All four of these sites have been visited by the author on two or more occasions and results have been extensively published, with further publications in the pipeline. Key stakeholders have been interviewed in the South African, Mozambique, Swaziland, and Zambian sugar industries. The expanding literature on biofuel growing in the region is also used to further support conclusions.

3 Case studies

A number of documented case studies are available and some will be used as the basis of this paper. These include:

3.1 Jatropha studies

- Niqel, Chimoio area, Mozambique (data from Andrew and van Vlaenderen 2011; CES 2009; Mudombi et al. 2016; Romeu-Dalmau et al. 2016; von Maltitz et al. 2014, 2016; and personal observations)
- BERL, Malawi (data from BERL 2012; Mudombi et al. 2016; Romeu-Dalmau et al. 2016; von Maltitz et al. 2014, 2016; and personal observations)
- Projects in the Kabwe region of Zambia (Haywood et al. 2008).

There are also a large number of studies on collapsed projects. All these projects stopped operating before reaching a stage of sustainable seed harvesting and so there are limited data on 'good' aspects of project management. Although there are extensive data on the unsuccessful setting-up of projects, it is difficult to differentiate between, on the one hand, the impacts of bad management practices and the operational model and, on the other, the impacts of poor feedstock choice. Relevant papers include: Borman et al. (2012); Gasparatos et al. (2012, 2015); Haywood et al. (2008); Romijn et al. (2014); van Eijck et al. (2014a, 2014b); von Maltitz and Setzkorn (2013); von Maltitz et al. (2012).

3.2 Sugarcane studies

- Dwangwa, Malawi (data from CISANET 2013; Mudombi et al. 2016; Romeu-Dalmau et al. 2016; von Maltitz et al. 2016; and personal observations)
- SWADE, Swaziland (data from Mudombi et al. 2016; Romeu-Dalmau et al. 2016; Terry and Ogg 2016; von Maltitz et al. 2016; and numerous personal visits).

Furthermore, there is a recent review of sugarcane projects in a special edition of the *Journal of Southern African Studies* (Dubb et al. 2016).

3.3 Details of case studies

Niqel jatropha project, Chimoio area, Mozambique

Niqel is a large-scale jatropha project in the Chimoio area of Mozambique. It was established in a fairly standard way, whereby the developer requested land for the project through the *Duet* system and was initially granted planting rights to about 20,000 ha. An initial impact study (CES 2009) identified that a large number of homesteads were located on the land proposed for the development. Areas of mature natural forest were also identified. The impact study recommended that the project be limited to a small subsection of the original land identified. This would mean that only a small number of households would have to be relocated. The households in the area were identified as being exceptionally poor, engaging mostly in subsistence-type agriculture using a slash and burn practice.

Individual households were given a choice between being relocated and remaining where they were. A 5 ha 'island' within the plantation would be left for households that chose to remain. Most families chose to be relocated, and they were moved to an area close to the plantation, where Niqel undertook to make 1 ha of land available for agricultural purposes. Most households had wattle and mud-type houses thatched with local grass, so there was not a major cost associated with the relocation of homesteads.

Starting in 2009, about 6,000 ha of land was cleared of trees and planted to jatropha at a rate of about 2,000 ha per annum. Initially, locally collected jatropha seeds were planted and there was no selection for improved performance. More recently, improved varieties have been planted. Initially also, the jatropha was planted on heavier, clay soils, but experience showed that planting on sandy soils leads to better yields. Yields to date have been low—only about 0.4 t/ha—but apparently the most recently planted improved varieties are performing far better, already in their first year matching the yields of earlier plantings.

Harvesting is done by hand using local labour, with casual workers being paid according to the mass of seeds harvested. Casual labour is also used in planting new areas to jatropha. In addition, there is a team of full-time labourers conducting tasks such as road maintenance, opening of new land, security, and the other tasks involved in running the plantation. About 9 per cent of households who were in the area before the plantation was established have gained permanent or temporary employment; the rest continue with small-scale farming, those physically displaced by the plantation being allocated new farm land that Niqel helped clear.

BERL jatropha project, Malawi

The BERL jatropha project was set up as a smallholder-produced model in 2008. The basis of the BERL model is that farmers grow a hedgerow of jatropha around the border of their farms, and then harvest and sell seeds to BERL, which produces straight vegetable oil (SVO) for blending into transportation fuel. It was initially assumed that farmers would plant 500 jatropha trees and that this would earn them US$100 per year. Because the trees were on the boundary, they would not take away cropland. Also, since this land was already de-forested, jatropha trees would in effect be increasing standing biomass and therefore sequestrating carbon. This carbon sequestration benefit was sold to investors to help fund the project establishment.

In the early phase, BERL employed a large staff of facilitators, who worked with communities to sell the benefits of planting jatropha and to assist in getting trees established on the farms. Locally collected seeds were used, with no tree breeding. Initially, BERL also employed buyers, whose role was to go to individual farms to purchase seeds, but this was later stopped. Now commercial buyers purchase from farmers at the roadside and transport the seeds to BERL.

About 30,000 farmers have participated in the BERL programme over a wide range of districts in Malawi. In practice, most farmers planted far fewer trees than suggested by BERL, and by 2014, yields still fell far short of the expected 0.8 kg per tree. In fact, mean yields as measured in 2014 by von Maltitz et al. (2016) were only about 0.1 kg/tree. This low yield, more than any other factor, is likely to prevent widespread success of the project. Moreover, until mid-2014, BERL was unable to market the jatropha fuel, due to regulatory constraints. BERL built a dedicated oil press in Lilongwe, but low jatropha volumes required them to diversify into other oilseeds (mostly for food, not fuel, markets) to use the idle capacity. The project is still operational, but at lower than expected impact.

The basic model was pro-poor, and if jatropha trees had produced initially anticipated yields, the project would have been of major economic benefit to farmers, potentially doubling or better their annual cash income from farming. However, with current yields, which are an order of magnitude less than anticipated, and the relatively low profit to farmers, many farmers are losing interest in the crop.

Mali jatropha project, Kabwe region Zambia

Mali was a small-grower jatropha project where farmers were expected to plant 5 ha of their 7 ha farm to jatropha. Mali helped the farmers to set up their jatropha plantations and was to be the market for all seeds produced. The project was unusual in that farmers had relatively (by African peasant farmer standards) large land holdings. They therefore had surplus land that could be dedicated to jatropha. This would not impact on their ability to grow food crops for home consumption, but would have competed with other cash crops they could have grown on the land. However, most farmers allocated a far smaller proportion of their farm to jatropha.

When established, the nature of the relationship between the investor and the farmers was an issue of concern, as the farmers had to enter into a long-term (in some cases 30 years) and one-sided agreement with the company, whereby they were obliged to sell their crop only to the company. However, the project collapsed soon after establishment.

Dwangwa sugarcane (and ethanol) project, Malawi

Dwangwa is a combination of estate sugar plantations (6,500 ha) and outgrowers (1,734 ha irrigated and 3,040 ha rainfed) (Atkins 2015). There are outgrowers on irrigated plats as well as dryland outgrowers. The mill is run by Illovo sugar. Molasses as a by-product is diverted to an ethanol plant (Ethanol Company Limited, ETHCO) but the sugar is sold as such.

There are a number of organizations that assist outgrowers, including:

- The Dwangwa Cane Growers Trust (DCGT), which was government initiated in 1978 and is designed to give support services to farmers. It maintains the land and irrigation infrastructure in return for the first crop and 1.5 per cent of gross returns.
- Dwangwa Cane Growers Limited (DCGL), which purchases inputs from Illovo Sugar and sells them on to the farmers. It also provides credit, performs farming activities such as planting and cutting, and helps to negotiate prices. DCGL deducts 20 per cent of farmers' returns as a management fee.
- Dwangwa Sugarcane Growers Association (DSGA), which bargains on behalf of farmers and offers mediation with other service providers such as transport companies.

Some farmers have established alternatives to DCGL, as they are not happy with the high cost of DCGL support, as well as the lack of transparency. This can potentially give far higher returns (Table 1). However, since DCGT controls the irrigation, irrigated farmers are obliged to be members.

Table 1: Share of returns along the Dwangwa outgrower sugarcane value chain (2013)

	DCGL farmers	Other associations
Total returns on raw sugar	100%	100%
Illovo milling charge	40%	(40%)
Farmers' gross return on raw sugar	60%	60%
Illovo withholding fee	9%	9%
Management fee, input credit, and other services	22.5%	10.2–13.58%
Haulage charge	4.0%	5.0%
DCGT CESS	0.57%	0.57%
MRA tax	1.17%	1.17%
Total deductions	37%	26–29%
Farmers' net return	23%	34–31% [sic]

Source: CISANET (2013), reproduced with permission.

On rainfed areas, farmers typically farm on their own, as individuals, but are members of some organization, usually a trust, through which they market their cane and get additional support. Twelve competing trusts have formed. Atkins (2015) shows that it is these famers who get the greatest return on their investment, despite their yields being far lower than the irrigated farmers.

Irrigated farmers are obliged to be members of the DCGT, which oversees most of the management of the plantation but takes a large proportion of the farmers' profit, leading to discontent. Unlike those in the SWADE project in Swaziland (see below), individual farmers maintain their own fields, but they have no ownership in the trust, which they see as a major expense, despite the services it provides.

There have been claims that farmers have been evicted from their land without compensation (Butler 2014). Some of these claims date back 35 years to the original establishment of the estate. The claimants argue that Illovo, in collusion with chiefs, pushed them off their land. The company claims that the land was obtained legally and with due compensation to farmers (Mtika 2014).

SWADE sugarcane project, Swaziland

SWADE has helped groups of farmers to form small independent cane-growing companies. In effect, groups of farmers have pooled their land and ceded this to a private company, in which they hold shares. In practice, the farmers had to give back to the king the farmland that they held under traditional tenure laws and this land was then re-allocated to the company. Each farmer, regardless of the amount of land donated, was then allocated one share. This share allocation is a point of contention among farmers who had large landholdings, but it is justified on the basis that the land is only one component of the overall scheme and that government support in terms of irrigation infrastructure and technical assistance should be on an equity basis.

SWADE facilitates the loans for the irrigation infrastructure and cane management, which have to be paid back by the company. The scheme has benefited from extensive EU financial assistance. The company employs a professional manager and staff. Most labour, haulage, etc. is contracted out and the profit is shared amongst the shareholders after costs have been deducted.

A number of additional benefits include drinking water supplied to the farmers' houses, and access to water for food crop irrigation. Some farmers live within the cane fields, others in villages to the side. Additional projects such as vegetable growing have been started to increase revenue streams and create jobs. Many of the farmers engage in peripheral industries such as transport. This is easy for them to do, since they do not have farming responsibilities.

SWADE farmers have been able to meet or out-perform the adjacent industrial-scale plantations in terms of cane yield. An analysis by Mudombi et al. (2016) found that those owning shares in sugar companies had far lower multi-dimensional poverty than control groups from matched areas without cane, or matched households from within the same area. The projects are, however, not without problems. There is a background discontent as to how shares were allocated, with those that contributed large blocks of land feeling disadvantaged. Furthermore, after loan repayments, profits can be relatively low.

4 Key trade-offs

4.1 Land access

Probably the single most contentious issue relating to industrial crop development in Southern Africa is land access (Vermeulen and Cotula 2010; Hall et al. 2015a). If a community is farming biofuel crops on their own land, this is not a major issue, but it often is in cases where investors seek large areas of land for biofuel crops. The main concern is: if this land is allocated for biofuel, what happens to the people currently using the land and will they be better or worse off? This has both legal and ethical consequences.

The example of Dwangwa, though dating back to the 1960s, illustrates a pattern that still seems to apply to many large-scale projects today. Companies negotiate with chiefs and local leaders and, even if they have followed a legal process, the impacts on those actually living on the land can be devastating. Poor land tenure, land tenure regulations, and the common rent-seeking of chiefs and government officials mean that developments are often not in the best interests of local farmers. This can lead to situations where even successful projects continue to have smouldering land-related tensions many decades in the future. Most of the projects studied have attempted to deal fairly with tenure issues through a number of innovative mechanisms. How well this is achieved is, however, debatable, with some projects clearly disadvantaging local growers through overly binding legal contracts. Where jatropha projects have resulted in limited economic benefit, community expectations of local development are clearly not being met.

The wide-scale collapse of jatropha projects in the region (von Maltitz et al. 2014) is another issue of concern. Many communities give up their land on the promise of development, but when the projects collapse, the land does not automatically revert to the community; in most cases it stays with the state. The original landowners therefore lose both their land and the expected development from the project.

A report by the World Bank (Deininger et al. 2011), a series of reports by Hall et al. (2015a, 2015b, 2015c), and the work of Cotula et al. (2009) have highlighted both the large spatial areas that have been allocated to international investors for large-scale biofuel production and the many social problems encountered in these land allocations. The current land tenure is an underlying factor leading to community exploitation. Both tenure reform and better legislation are needed to resolve this problem.

With the exception of South Africa, where the majority of the land is private freehold land, all Southern African states have most of their land in some form of communal tenure. Exact arrangements vary by country and location, but the simplified view is that this land is owned by the state or the king, with communities allocated traditional usage rights. The state is empowered to re-allocate communal land to investors for project development, including the growing of a biofuel crop. In some cases land is earmarked for commercial purposes, often under some form of long-term lease. This land is typically already allocated to a leaseholder. In Mozambique, the history of war means that some land is currently formally unallocated, though informally there may be community members resident on the land.

Land tenure reform is an ongoing process in the region. Creating enhanced tenure security for indigenous land users is a normal component, but equally the countries want to ensure that there is the opportunity for large-scale development. In most situations the large-scale land leases are entered into between governments (national or local) and the developer, and not between the developer and the local communities. In Zambia, tenure is actually transferred from the community to the government, which then leases the land to the investor. In Mozambique, there is the *Duet* system, whereby the government allocates long-term lease rights to land.

As was found in the case of the Niqel case study, this right to develop biofuels might well apply to land populated by a series of local communities. At Niqel, though the right to establish a jatropha project was granted, members of the local communities had the right to choose to stay on the land or be relocated to surrounding areas. As far as we know, this is a unique way of dealing with the land issue. It also appears that the local community could halt the project if they were strongly dissatisfied with it (personal communication with Niqel managers). In the Niqel case the project seems to have done better than many other large-scale projects in terms of accommodating existing land users. In the light of the initial environmental impact assessment, the extent of the project was reduced to include only areas with low population density. In addition, new land was cleared to accommodate relocated families. The process was, however, not without contention. Only a small percentage (about 9 per cent) of households in the area have been able to access job opportunities, and at the time of the author's last visit to the site, in late 2014, no major income was being generated from the project.

There is growing international and local concern over what are being referred to as land-grabs, where investors are gaining access to vast areas of land, often to the detriment of those currently resident on it. Though governments may stipulate that compensation must be paid to any people currently on the land, the Southern African experience has been that this is often trivial, possibly covering only the cost of physically moving the homestead. There is seldom any guarantee that those dislodged from the area will gain employment on the plantation.

Exceptions to the above are where the local land users become the feedstock growers in what are typically referred to as outgrower schemes. Even in these there might be winners and losers, not all affected households being able to become part of the scheme.

In the SWADE model in Swaziland, the existing land holders pooled their land and formed a cane-growing company. In this case they literally ceded their land to the company (in practice transferring it back to the government, which then transferred it to the company). Thus, they ceased being land owners and became company shareholders.

A more common mechanism is one in which each landowner is part of a large cooperative that farms the land. In the Malawi Dwangwa irrigated outgrower projects case, farmers farm their individual fields within a larger block of sugarcane plantations. This appears to be the most common outgrower model in the Southern African region.

Even when land is allocated to nationals from the country of the project, these are not necessarily the current land users or rural peasantry. For instance, in their study of a subsample of farmers allocated land as part of a land reform process in Zimbabwe, Scoones et al. (2016) found that almost all were either civil servants, estate employees, or 'war veterans'.

The old approach, in which it was assumed that simply by investing in an area a foreign investor was going to bring benefits, needs to be challenged. A model in which local communities become true and empowered 'owners' of the project would seem to be the ideal option. Community members need their interests, including their land, to be protected, even if the project fails. The community members should also not be carrying an undue proportion of the risks, and should be able to have fair access to the benefits. In this regard, the SWADE model seems to have many positive aspects. Underpinning all of this is a need for tenure reform in most Southern African Development Community (SADC) countries. The issue is not about blocking foreign investment, but rather ensuring that it brings true benefit to existing land users.

4.2 Biodiversity

Unless biofuel is grown on existing croplands, it is almost always going to result in biodiversity loss, and if large-scale biofuel is envisaged then this loss could be substantive (Blanchard et al. 2011; von Maltitz et al. 2010), though much of the biodiversity loss can be mitigated through strategic planning, for instance by using the High Conservation Value tools provided by ProForest. (von Maltitz and Sugrue 2011). It is also possible that to an extent biodiversity impacts can be offset by the creation of dedicated conservation areas. This has happened in Swaziland, where many of the managers of the sugar estates have invested their own money in the purchase of an area that they use for lifestyle and conservation purposes. This land is now better preserved than it would have been under customary land management.

In the case of the proposed Bagamoyo sugarcane project in Tanzania, initial plans would have led to some of this area receiving higher conservation status than is the case under the no-project option. People moved into the area in an opportunistic manner on the assumption that the project would be initiated and create job opportunities. These migrants then converted rangeland to agricultural land and hunted out indigenous fauna, both actions leading to biodiversity loss, despite the project not being initiated.

In the case of the Niqel project, large areas of indigenous woodlands were cleared to make way for jatropha planting. The environmental impact study mapped out the areas of 'high' forest for conservation, but despite this it is clear that many areas of dense vegetation were cleared, with an obviously high impact on biodiversity. It should be noted that, since jatropha is a perennial tree crop, and given that an understory of diverse grass is establishing, this impact will be less than if the area had been cleared for a monoculture of an annual crop. Furthermore, much of the mammalian and bird diversity in the area had already been depleted from over-harvesting (even though all hunting is illegal) and much of the area was already being cleared as part of a slash and burn rotation of subsistence crop production.

In the case of the Malawi BERL project, jatropha trees are being introduced as hedgerows to existing agricultural fields. Minimal biodiversity impacts are expected unless this depresses crop yields, resulting in indirect land use change. The introduction of a tree layer in the fields could even have a marginal positive impact on biodiversity.

4.3 Greenhouse gas emissions

The ability of biofuel crops to mitigate GHG emissions varies widely between crops, management practices, and the nature of the land where the biofuel crop is grown. Where indigenous vegetation is cleared for biofuel crops, there is also the potential for land use change GHG emissions. In addition, there is the potential for indirect land use change impacts when farmers open new fields to compensate for fields (and the food they produced) being lost to biofuel crops.

Sugarcane, as a biofuel crop, appears to have one of the best overall positive impacts on reducing GHG emissions due to its high per hectare yield and comparatively low lifecycle emissions (de Vries et al. 2010; Menichetti and Otto 2009; Zah et al. 2007). Actual emissions data from Southern Africa are scarce, no studies being available on full emissions under Southern African-specific circumstances—which will require case-specific data related to actual energy usage and the way that energy is generated. A key factor in project-specific emissions will be the power usage for irrigation and the degree to which bagasse is used for electricity generation. Mills can generate substantial amounts of electricity from bagasse, and this can help to offset the electricity used, for instance, in irrigation. However, most mills are fitted with low-pressure steam systems that generate only a fraction of the electricity that would be available if high-pressure systems were used. Most studies suggest that sugarcane could pay back the land use change component of GHG emissions quite quickly. Romeu-Dalmau et al. (2016) found that the land use change impacts from GHG emissions were relatively small in the case of the Swaziland and Malawi sugar plantations, as much of the high-density forest had already been lost from the area.

By contrast, jatropha plantations, if replacing savanna or miombo woodland, are likely to incur quite high land use change carbon debts. Given that the biofuel yields from jatropha are relatively low, carbon payback periods will be long (Romeu-Dalmau et al. 2016; von Maltitz et al. 2012). One exception is where jatropha is planted on existing cropland or degraded land. In this scenario jatropha trees might have a positive impact on land use carbon stocks (von Maltitz et al. 2014).

Lifecycle GHG emissions from other biofuel crops are largely absent from the region. In general it is likely that most oilseed crops would have effects similar to or worse than jatropha, alternative ethanol crops mostly being worse than sugarcane. Where ethanol is derived from a seed such as maize, the results are especially bad.

4.4 Food fuel trade-offs (local and national)

One of the most contentious issues relating to biofuel expansion is the impact it might have on food security. Since food security is already low in most Southern African countries, this is a major concern in the region. South Africa's initial entry into biofuel was to focus on maize-based ethanol, it was private sector driven, and six distillery plants were planned for Bothaville. The South African government's biofuel strategy, however, dealt a fatal blow to these plans by banning maize as a feedstock, as it was feared that this would impact on South African food security. The maize industry, on the other hand, argued that it was being constrained by a lack of a market rather than a lack of production potential.[1]

For other Southern African states the situation is even more complex. Zimbabwe, Zambia, and Mozambique could all conceivably outperform South Africa in food crop production, but in

[1] In most years South Africa can far exceed national maize demand, although in drought years such as 2015/16 the national maize quota is not met and maize must be imported.

practice have far lower production. This is due to a number of factors, many of which relate to constraints inherent in the small-scale peasant farmer approach to food crop production.

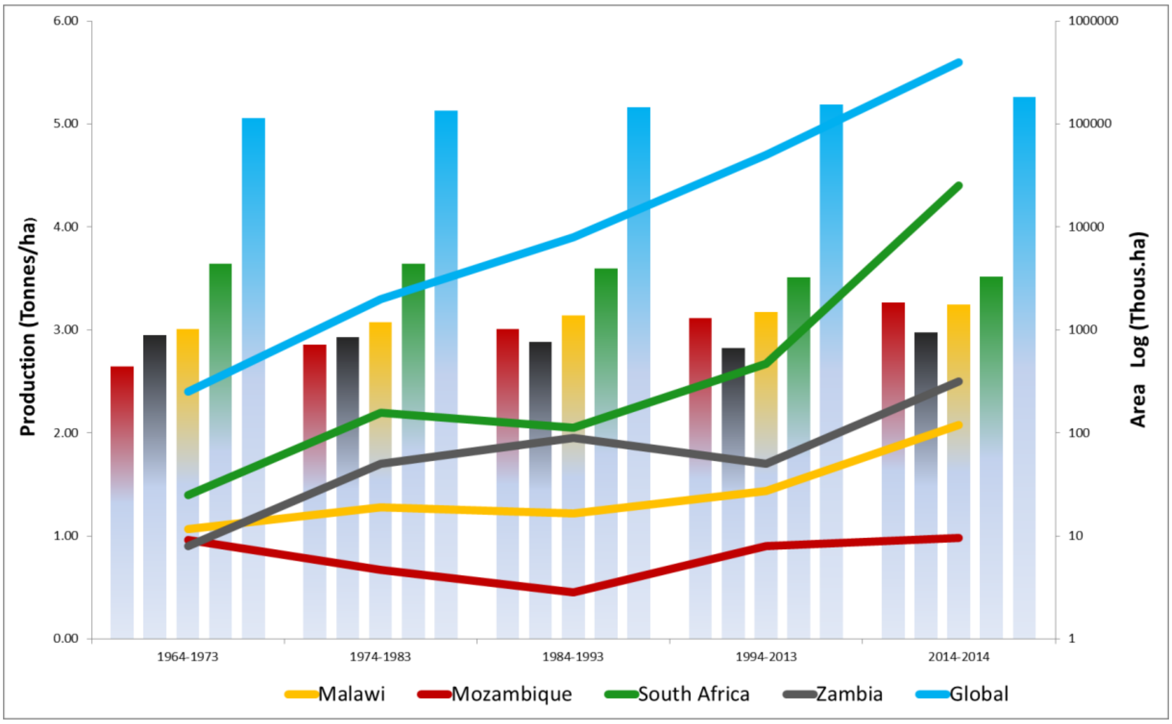
With the exception of South Africa, Southern African countries had low food security before the introduction of biofuel, and the drivers of this food insecurity have nothing to do with biofuel growing. This means that food insecurity is likely to persist with or without the introduction of biofuel, unless the underlying causes are identified and dealt with. The key question is: will the introduction of biofuel increase food security or will it deepen food insecurity? Convincing arguments have been put forward for both outcomes (Diaz-Chavez 2010; von Maltitz 2014).

From the case studies, there was no strong evidence to suggest that food insecurity had increased, either in the total amount of food produced or at household level. There was some evidence that households that had engaged in biofuel production, either as labourers or as sugarcane outgrowers, were reducing food insecurity from cash income from biofuels. For outgrower jatropha projects there was very limited positive impact, due to low yields and low prices, so there was no evidence of significant positive benefits. Although the BERL outgrower model's use of field boundaries meant that there were also no negative impacts, von Maltitz et al. (2016) point out that the long-term impacts of jatropha planting on surrounding food crops are currently unknown. If jatropha were to perform as a crop (i.e. new varieties are developed that give acceptable yields) or an alternative, but similar, crop with high yields were found, then the type of model suggested by BERL may well have strong poverty-reduction impacts (von Maltitz et al. 2016).

If vast areas of countries are converted to biofuel production, this could impact on national-level food security due to loss of food-producing areas. This could occur even if no local food security impacts were observed. However, given the gap between actual and potential yields of food crops in Mozambique, Zambia, and Zimbabwe, loss of food-producing land could easily be mitigated by food crop farmers' use of improved management practices, such as increased use of fertilizer. The impacts of the maize fertilizer subsidy in Malawi clearly illustrate how yields can be increased if the cost constraint of fertilizer is removed (Channing et al. 2015). Better management using organic methods could also greatly increase yield at a lower cost. As Figure 1 illustrates, yields in most Southern African countries have stayed relatively constant since the 1960s (rising by less than 1 kg/ha), whilst international yields have been increasing. There are no biophysical reasons why countries such as Zimbabwe, Zambia, and Mozambique should not be able to produce close to, or better than, the world average. The constraints preventing this tend to relate to market access, the economics of small-scale production, access to inputs, and access to technology. Figure 2 shows that for sugarcane, where good management is taking place, yields are in fact better than the global mean.

Impacts due to drought will remain an issue in the region, and potentially increase with climate change. There are few data on how the use of land for biofuel production might help mitigate, or might add to, the negative consequences of drought.

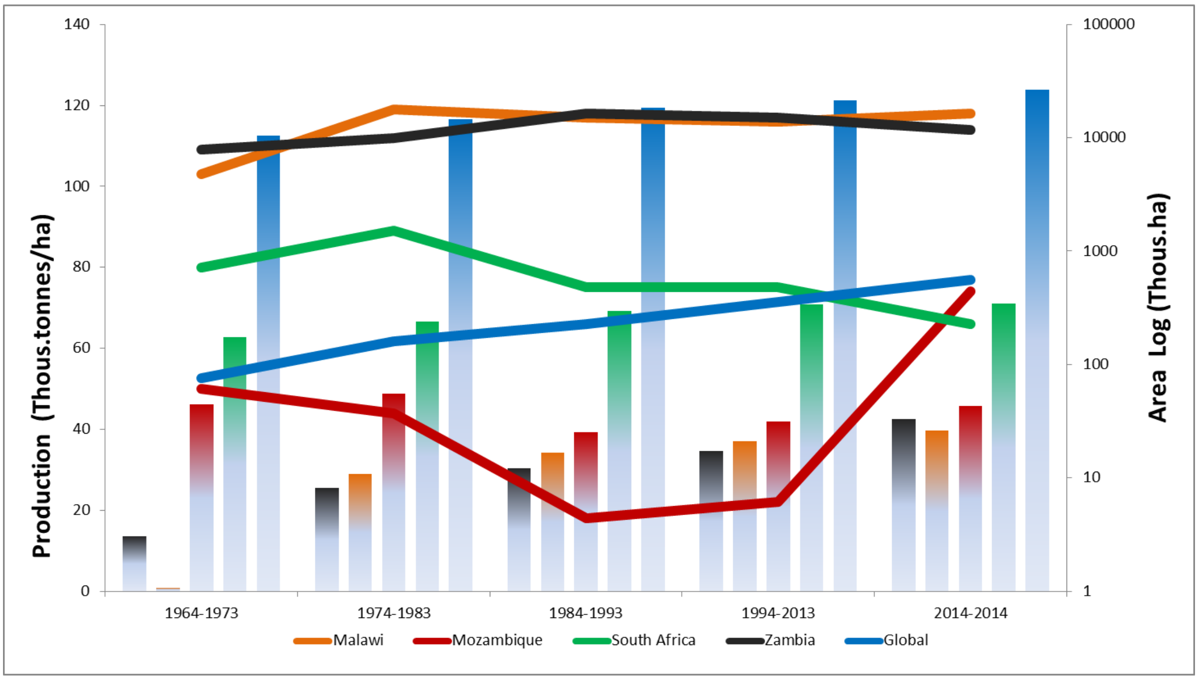
Figure 1: Mean area planted to maize and maize production in selected Southern African countries compared with global trends



Note: Bars indicate the logged area under cultivation, whereas the lines show a linear interpolation between the mean decadal maize yields.

Source: FAO data.

Figure 2: Mean area planted to sugarcane and sugarcane production in selected Southern African countries compared with global trends



Note: Mozambique yields are now globally competitive as projects have been rehabilitated over the past few years.

Source: FAO data.

4.5 Fuel provision (local)

Biofuel expansion in Africa has tended to have one of two very different purposes: either to provide fuel for local use or to provide fuel for national fuel blending (Gasparatos et al. 2012; Haywood et al. 2008; von Maltitz and Setzkorn 2013).

All the case studies discussed, and the study as a whole, focus on national fuel provision. It is, however, useful to recognize that some of the promotion of biofuel has been around fuel provision for local, non-transportation fuel use. Projects set up with this objective tend to be very different in nature from projects established for the production of transportation fuel blends.

Probably the best researched example of such a project is the set-up of jatropha-based generators in rural Mali (Mali Folkecenter). No recent data on the long-term development of this project could be found, though early experience suggested that insufficient jatropha seeds and oil were being produced for jatropha to be a main component of the fuel mix, and instead the generators were being run on diesel fuel. Even if this project was to run sustainably on jatropha, the electricity generated would not be sufficient to allow households to cook with electricity. Rather, the power would be used for lighting and some light industry.

The only example of an attempt to use biofuel for cooking is the programmes aimed at introducing ethanol stoves. The biggest project of this nature in Southern Africa was the CleanStar initiative in Maputo, which aimed to use ethanol (from a distillery in Beira) produced from cassava. Over 300,000 ethanol stoves were sold, but their use has been minimal—typically only for rapid cooking such as making tea—with households still doing most of their cooking with charcoal (Mudombi et al. 2016). The ethanol production component of CleanStar has now collapsed.

A second example of the production of ethanol for cooking was a project run by a South African farmer, who first produced ethanol from maize, and later from tropical sugar beet. This was done from a small, largely homemade still, proving that ethanol production can be downscaled and kept relatively simple.

A key feature of all the projects aimed at making biofuel for local use or for cooking is that the fuel is never used for cooking in the area where it is produced. Either it is used in urban markets far from the production area, or it is used for lighting.

4.6 Fuel provision (national)

Malawi is currently the only Southern African country with an operational biofuel market. Malawi's blending of ethanol into petrol predated the global move to biofuels (von Maltitz and Brent 2008).

Biofuels are a potential substitute for expensive imported fossil fuels, having the dual benefits of saving foreign exchange and creating a huge number of local employment opportunities. Many Southern African countries have been discussing mandates for blending, but as yet these discussions have not been formal enough to start an industry. Blending ethanol with petrol is quite complex, as it affects octane levels and requires storage in containers that are certified for ethanol. Nevertheless, blending up to 20 per cent is technically feasible (Brazil currently uses a 27 per cent blend) and higher blend ratios (e.g. for use in dual-fuel cars) are achievable.

Biodiesel is far less complex than ethanol, and high-quality biodiesel should be able to replace conventional diesel at any blending ratio with little impact. Among the few concerns are that old engines have rubber seals that might be damaged by biodiesel and that biodiesel tends to 'clean' the fuel tank, which can cause blockages in fuel filters.

National fuel mandates can be achieved from relatively small areas of biofuel. It has been calculated that almost half of Mozambique's 3 per cent biodiesel mandate could be achieved from the 6,000 ha Niqel project, provided 3 t/ha of jatropha seeds are harvested. Malawi's 20 per cent target can be met from 200,000 small-scale farmers (about 10 per cent of all farmers) if each has 500 m of jatropha hedgerow and yields of 1.3 kg per tree. Unfortunately, both planting and yields to date have fallen far short of these targets, which are looking distinctly unlikely unless new, high-yielding verities of jatropha are developed (von Maltitz et al. 2016).

Table 2 gives (slightly dated) estimates of the amount of land required to meet total fuel replacement (as a percentage of total land) or a 5 per cent blending target (2 per cent for South Africa). As can be seen, the amount of land that would be required in either case is relatively trivial for all countries other than South Africa: even if current food cropland was included, South Africa would not have sufficient agricultural land to meet its national fuel need, though it should be able to meet its low blending target on potentially available land. Mozambique, Tanzania, and Zambia, on the other hand, could meet all of their fuel needs from biofuel using only about 1 per cent of their land surface. Meeting their blending requirements requires less than 30,000 ha in all cases. As can be seen from the table, substantial job opportunities would be created if countries were to convert fully to biofuel.

Table 2: Estimates of land needed to meet 5 per cent (2 per cent for South Africa) biofuel targets and total fuel needs, and jobs that would be created

	Botswana	**Namibia**	**Tanzania**	**South Africa**	**Mozambique**	**Zambia**
Diesel use in l/yr X 10^6	281	445	667	7,987	381	327
Petrol use in l/yr X 10^6	301	325	202	10,289	107	210
% of total land needed to meet total transport fuel needs	0.9	0.9	1.2	14.6	0.8	0.8
Land needed to meet biofuel targets in ha	26,078	38,917	53,855	307,375	30,631	56,286
Estimates of jobs created to meet biofuel targets*	12,251	18,608	26,399	142,919	15,036	27,046
Estimates of jobs created to meet national fuel usage*	245,028	372,160	527,980	n/a	300,712	270,458

Notes: All calculations based on sugarcane at 65 t/ha and jatropha at 2 t/ha as feedstock for ethanol and biodiesel, respectively. Values are not linked to specific country/growth conditions and assume that suitable land is available.

* These figures are based on 0.5 job per ha for biodiesel and 0.33 job per ha for sugarcane, as used in Econergy (2008). If a more mechanized biodiesel crop was used, such as soybean, the labour required would be greatly reduced. Most would be low-paying labourer jobs.

Source: Based on von Maltitz and Brent (2008).

4.7 Export markets based on CO_2 mitigation

The initial boom in biofuel projects in the Southern African region was largely driven by a perceived large European market for biofuel as a consequence of the Renewable Energy Directive (Directive 2009/28/EC). It was assumed that Europe would not be able to fulfil this mandate of locally produced biofuel and hence there would be a large international market for sustainably produced biofuel—fuel that would have to meet European certification requirements.

Europe's biofuel directive is now under review, however, and has modified targets in keeping with member state circumstances. This seems to have diminished the strength of this driver for biofuel production outside Europe (EEA 2016). Moreover, the price of crude oil has dropped substantially from its highs of the mid 2000s, meaning that the potential value of biofuel as an export crop has reduced significantly.

Of the case studies investigated, none is currently considering export markets. All biofuel will go to meeting national mandates.

4.8 Infrastructure provision

The development of biofuel crops can have a major impact on rural infrastructure development. In Swaziland, the government saw that the infrastructure that had been created for sugar development could be used in other projects (UNCTAD 2000: 6). Sugarcane-growing was a means to achieve dam and irrigation infrastructure, which might later be used for other crops rather than as an end in itself (Terry and Ogg 2016). The existence of the sugarcane industry has also resulted in both the industry and government developing an extensive network of road and bridge infrastructure that would not have existed in the absence of the sugar cane industry.

Secondary infrastructure and services such as shops, hospitals, and schools have also been established due to the general economic growth in the region. At its project in Mozambique, Niqel has contributed substantially to providing and maintaining an all-weather road network in the region of its plantation. Many small shops (in South Africa referred to as spaza shops) have been set up due to the increased spending power of workers. A jatropha project in Southern Mozambique reported a substantial increase in these shops during its establishment phase (the project has since collapsed).

Smallholder projects such as BERL and the Zambian Mali project, on the other hand, do not directly result in improved infrastructure. A possible conclusion is that large commercial projects are more likely to result in direct and indirect infrastructure development, whilst this is less likely from smallholder-type projects.

4.9 Population movement and impacts of migrant labour

A negative impact of biofuel developments is that they tend to attract migrants to the project sites. This is due to the expectation of paid labour. Some of these people may find paid jobs, but many may not.

A concern of many biofuel projects and existing sugar projects is that much of the labour is seasonal, low-paid, and labour intensive, such as cane-cutting—jobs which the people within the biofuel growing area often do not want. In the case of the Swazi and Malawi sugar projects, it appears that much of the seasonal labour is migrant labour, although at Niqel, most of the unskilled labour is sourced locally.[2]

This shift may bring about labour compounds of predominantly young men who are away from their families, which can lead to secondary problems such as high alcohol consumption and prostitution. Very little data have been published on these impacts.

Furthermore, in the case of the proposed Bagamoyo EcoEnergy project in Tanzania, it has been postulated that the large movement of people into the area, attracted by the prospect of the biofuel project, has had major impacts on wildlife.

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[2] The issue of labour is irrelevant in the BERL model, as all labour is from the farmers and their households.

4.10 Impacts of seasonal labour

Seasonal labour brings with it two problems: low job security and the fact that there is employment only for a portion of the year. The jobs are often of poor quality in the sense that pay is low and labour requirements high. As has been stated, cane-cutting is well known for being an unpleasant job. Furthermore, there is often a gender bias, with few women employed in these jobs. At Niqel, jatropha pickers were mostly women, and they were badly paid.

4.11 Impacts on livelihoods

The motivation for many African governments in supporting biofuel projects is that they will bring development into deeply rural areas (Gasparatos et al. 2015; von Maltitz and Stafford 2011). The assumption is that the projects will impact positively on the local economy and help uplift local communities.

Studies considering this show mixed results. There is general concern in the literature that sugarcane projects typically provide mostly low-value manual jobs that pay at the minimum rural wage level, as set out nationally, or slightly above the national minimum wage. Nevertheless, given that these jobs are in areas with no other options for waged income, this can represent a relatively substantial monetary injection into the local economy.

A multi-dimensional poverty study by Mudombi et al. (2016) found decreased poverty linked to sugar projects. Though not yet fully analysed, wealth and food security are expected to follow similar patterns. The impact of sugarcane farming on rural livelihoods is hotly debated in the development literature, with strong arguments in favour of and against sugarcane (see Scoones et al. 2016).

Jatropha projects, to date, have had limited or no positive impacts on livelihoods (Mudombi et al. 2016).

4.12 Impacts of project collapse

The collapse of almost all jatropha-based projects in Southern Africa is an issue of major concern. This is not an inherent fault of biofuel, but rather the result of the fact that jatropha was not tested as a crop before wide-scale project implementation. The biggest concern with jatropha is that in plantation-based systems it has yielded only a fraction of what investors had expected.

The collapse of large-scale jatropha projects has led to social hardships. In at least one instance, labourers were left without pay for over a year (von Maltitz et al. 2012), while in another, more than 90 per cent of the labour force was retrenched (Carrington et al. 2011). Many projects have been totally abandoned and it can only be assumed all workers have lost their jobs.

In the case of smallholder jatropha projects, farmers have lost substantial investments in time and possibly incurred direct monetary costs in establishing a jatropha plantation. There is also the opportunity cost of land and labour that could have been used for other activities. In many cases, there is no clear closure of the project, but rather the investor supporting the project simply disappears and farmers later discover that they have no outlet for their seeds. Jatropha is particularly problematic in the sense that it is toxic and cannot be used in markets other than the biofuel market. This same constraint would not exist for other oilseed crops such as soybean or sunflower, which could be diverted to food oil or animal fodder markets.

Sugarcane has typically been used for sugar, not biofuel, production in Southern Africa. Sugar plantations have proven to be resilient, many dating back 30 to 40 years. For sugar, there is also the benefit of a potential dual market, as is the norm in Brazil, where sugarcane is diverted to the sugar market when the sugar price is high and to the ethanol market when the ethanol price is high.

4.13 Water resources

Jatropha projects probably have little or no impact on water resources (Gush and Moodley 2007). During the establishment phase there is likely to be increased erosion, but subsequently the impact is likely to be minimal. Holl et al. (2007) have shown that in South Africa, jatropha requires much the same amount of water as natural vegetation. In the BERL model, the jatropha trees may well reduce erosion.

On the other hand, sugarcane in the region tends to be irrigated, which has major impacts on streamflow.

4.14 Forgone opportunities

A key question for biofuel projects is: what alternative use could have been made of the land, labour, and capital. German et al. (2011) argue that jatropha projects give a lower return to land and labour than subsistence farming. However, they were investigating collapsing jatropha projects and this result should be considered in that light, and not necessarily be extrapolated to other biofuels. Biofuel crops are naturally relatively low-value, high-volume crops. Far higher-value crops might be grown, especially if irrigation is provided. However, most high-value crops do not attract FDI. The SWADE project has attempted to integrate small amounts of high-value horticulture into the overall project as a way of creating additional value and job opportunities.

4.15 Who carries the risks?

In developing projects, the risk can be carried differentially by different role-players. Dubb et al. (2016) suggest that in some sugarcane projects, the farmer may carry a greater risk than the mill. In bad years the farmer may be carrying a loss, whilst the mill may still enjoy a profit.

The Mali project in Zambia had farmers agreeing to a very stringent contract that would have disadvantaged them for years. However, when the project collapsed, they carried the opportunity cost of all their jatropha activities, without any recourse to the company, which had not fulfilled its obligations.

The SWADE model has the farmers carrying a large proportion of the risk of their farming operation, but this also gives them access to the potential rewards.

5. Institutional aspects of biofuel projects

5.1 Impacts of feedstock choice on available production models

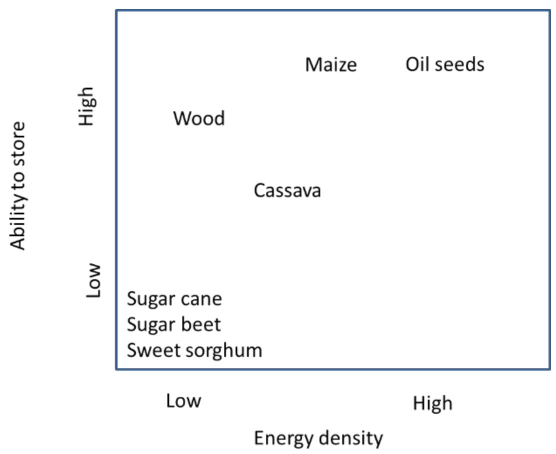
Biofuels need to be produced in bulk if any meaningful impact on the total transportation fuel demand is to be met. In an ideal situation there should be high yield per hectare and the distance to the processing facility should be short. This general principle applies to any biofuel, but there are differences between different feedstocks that make the transportation issue more or less critical. Sugarcane has a relatively low energy density (producing 70–80 l ethanol per wet tonne) and, more importantly, starts to lose quality soon after harvesting, which means that production needs to be close to the milling plant. Starch crops such as Cassava have an intermediate energy density (producing 150 l ethanol per wet tonne). Dry grains like maize have a higher energy density (410 l ethanol per wet tonne) and can be stored, so the distance to processing plants can be greater. Oil crops like soybean have a high energy density (250–300 l biodiesel per wet tonne) and can be transported relatively easily. They can also be crushed and the oil extracted locally, leaving only the high-energy-density oil to be transported.

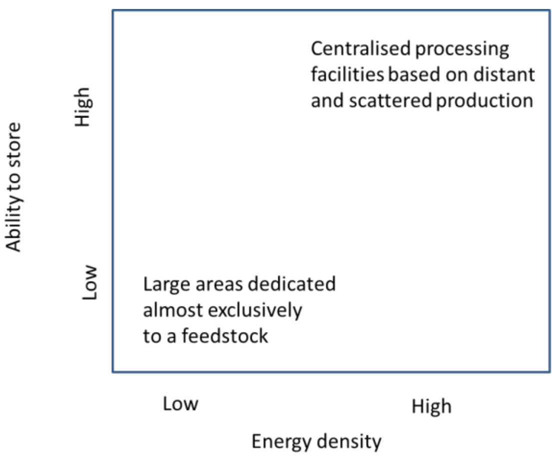
A consequence of this, especially relevant to sugarcane, is that it is important to have large consolidated production blocks from which high yields (minimizing transportation distances) are achieved. For maize, soybean, or jatropha it may be possible to have widespread production, with seeds transported over longer distances.

The relationship between energy density and storage potential for various biofuel crops is shown in Figure 3a and with the types of industries and production models are shown in Figure 3b.

Figure 3a: Mapping of biofuel crops against energy density and storage potential (right)

Figure 3b: Mapping technologies against energy density and storage potential of biofuel feedstocks (left)





Source: Author.

From the four-quadrant diagrams above, it is apparent that feedstocks that fall into the low–low quadrant require unique farming models, whilst feedstocks in other quadrants have greater flexibility.

Low energy density–low storage potential feedstocks

Most of the sugar crops fall into this category. These crops are expensive to transport due to their low energy density, and ideally need to be processed within a day of harvest. For instance, sweet sorghum loses 16 per cent of its sugar yield within three days of harvesting (Reddy et al. 2008). All the feedstocks identified in this category relate to ethanol production. For industries to be based on these feedstocks, it is imperative that processing facilities are surrounded by high-volume feedstock-producing farms. This probably means that most farming in the area needs to be dedicated to the feedstock and that high-production farming methods are a prerequisite. This is the model of existing sugar mills.

Since these feedstocks are linked to ethanol, the normal assumption is that they need to be linked to high-volume factories, which reduce costs through benefits of scale. One way of reducing transport costs and crop degradation may be to conduct partial processing in the growing area (i.e. roller mills to extract the sugars from the cane). This would allow a higher-density product to be transported to the final ethanol production plant, which could then be a greater distance away. This model has been suggested as a mechanism to expand the smallholder growing area in Dwangwa for ethanol production. However, a counter-problem is that it would reduce access to bagasse as a fuel at the distillation plant, or for other uses such as electricity co-generation.

A consequence of the characteristics of feedstock in this category is that there is a need for a high degree of synergy between the growers and the mill. For instance, the scheduling of harvesting is a key consideration, as the mill needs to receive a predictable volume of feedstock on any particular day. It also means that the processing facility needs to be working closely with surrounding communities to ensure that sufficient feedstock is being produced to meet the mill's throughput volumes.

A good feedstock for this type of processing plant is one that can be harvested all year round. Sugarcane is relatively good in this regard, being harvestable over many months of the year, the exact amount being linked to local climate. Tropical beet may be able to stay dormant in the ground for many months prior to harvesting, but needs to be processed rapidly once harvested. In the case of sweet sorghum, there is likely to be a relatively short period in which the crop can be harvested to achieve the best sugar returns. This could be a constraint to the use of sorghum as a feedstock.

The establishment of irrigation infrastructure also requires the consolidation of production into restricted areas with high yields to reduce the cost of the infrastructure and increase the return on the investment. Irrigation infrastructure often needs loan financing, which is easier to obtain when a single large entity is involved. In instances where small-scale farmers form part of an irrigation project, some form of overarching institution is needed to facilitate the loan and take responsibility for its re-payment.

Low energy density–high storage potential feedstocks

Feedstocks such as timber (a second-generation biofuel) can be relatively easily stored, but transport costs are high. Most of the same considerations of low-energy-density, low-storage feedstocks apply, except that these feedstocks are harvested during short periods of the year, while the processing mill can run all year—something not possible with sugar feedstocks, whose mills are forced to shut outside the harvesting period. The scheduling of the harvest is also less critical than in the above model.

High energy density–low storage potential feedstocks

Feedstocks that have high energy density and high storage potential can be transported over relatively long distances. These feedstocks can theoretically be grown in low density on individual farms, with other cash crops. Although they could be grown in large-scale plantations, this is not a necessity.

From a processing plant perspective, the plant can be in a centralized location such as a large city, with feedstock coming from many relatively distant locations. This is the model of the BERL project in Malawi. Transportation costs are still likely to be a key factor, but less so than with low-energy feedstocks. The mill can stockpile feedstock during the harvest season to be processed over the year.

Cassava is a crop that could be considered as intermediate on both these parameters. Its relatively high energy density means that it can be transported more easily than sugar crops and, if well treated, can have a slightly longer shelf life. Intermediate processing can also produce a dehydrated form, which can be stored and transported more easily. Mobile facilities to do this are being used by the beer industry in northern Mozambique.

High energy density–low storage potential feedstocks

No crops were specifically identified as fitting this category. Any crop that fitted this category would require rapid transportation to a processing facility. Logistics and scheduling would be important considerations.

5.2 Impacts of processing technology on feedstock production models

The two competing first-generation feedstocks, ethanol and biodiesel, tend to pose different production demands.

Ethanol is typically considered a technology that benefits from being operated on a large scale, despite the fact that simple distillation can be carried out on almost any scale. Furthermore, the ability to produce anhydrase ethanol (i.e. ethanol of over 99 per cent purity) is best achieved at the scale of hundreds of megalitre plants. Maize ethanol plants in the USA typically have more than a 200 million litre per year capacity, with up to 1,350 million litres nameplate capacity (Renewable Fuels Association 2016). Brazil's biggest ethanol plant produces 2,500 million litres per year and requires 357,000 ha of sugarcane as feedstock, i.e. a region of 356 km radius around the mill fully dedicated to sugar. For the smaller (200 million litre) distilleries, 30,000–40,000 ha of sugarcane would suffice.

Although the efficiency argument of large-scale ethanol plants is well established, there are counter-arguments in favour of smaller-scale plants. These increase the per litre ethanol cost, but have a multitude of social and environmental benefits that might offset the greater production cost (Ortega et al. 2007). The blending of ethanol and petroleum is also more complex and needs to be done at centralized facilities.

Biodiesel plants are more easily scalable than ethanol plants, though larger plants tend to reduce costs. Larger plants also tend to mean more efficient chemical extraction techniques. In addition, larger plants are often more environmentally friendly in that they can afford to put in place good waste management processes. On the other hand, the properties of biodiesel are such that it can be directly used in any blend with diesel. This means that a small rural biodiesel plant could theoretically provide for local diesel needs, negating transport costs of the feedstock and/or processed fuel.

Second-generation technologies, because of their greater complexity, are all likely to need large processing facilities. These technologies will probably be based on lingo-cellulose or simply total biomass, and by their nature will need large volumes of low-energy-density biomass to be delivered.

5.3 The concerns around large-scale commercial plantations

From an efficiency perspective, large-scale commercial plantations benefit from scale. This reduces pro rata input costs and makes it possible to install the expensive machinery necessary for maintaining modern biofuel feedstock production processes. From the perspective of the mill and foreign investors, having large feedstock production estates reduces the risk of an irregular feedstock supply from outgrowers, allows greater control over the feedstock production process, and ensures that feedstock will be available in time for the start of production. In many instances, investors want their own estates to provide some of the feedstock, even if a large proportion of the feedstock is to come from small growers.

From a social perspective, large-scale plantations are not inherently good or bad models for producing biofuel crops. They have, however, been widely criticized historically for the way social issues have been dealt with, particularly during the establishment phase (see above). There is also concern that they do not bring the degree of local development anticipated, and are often highly unequitable in terms of profit-sharing. In essence, such projects are accused of displacing local farming practices and livelihoods, with the benefits from the biofuel (or other large industrial crop plantation) not going to those who have been dispossessed of the land. Where locals obtain paid labour from the projects, it is typically low-paid manual work. The fact that a large investment might have fully complied with the law of the country in which it is operating does not mean that the project is considered fair and equitable. In many cases national legislation provides limited security for the local rural population—a problem compounded by rent-seeking by the government and traditional authorities. The fact that in most Southern African countries the land is under some form of traditional tenure underpins most of these concerns.

Recent literature on large-scale agricultural development projects (e.g. Cotula et al. 2009; Cotula 2011; FAO 2011; Hall and Sulle 2014; Hall et al. 2015a, 2015b, 2015c; Mousseau and Mittal 2011a, 2011b) identifies the following key concerns:

- Poor community consultation
- Investors dealing badly with communities
- Investor promises not being kept, particularly about jobs
- Investors exaggerating potential benefits
- Projects used by the political and economic elite to acquire land or business shares
- Poor performance of recent large-scale land investments in terms of reducing poverty—in many cases much of the land remains idle
- Corruption
- Ridiculously small amounts of compensation to families who are expected to move their homes and farms to new areas
- Projects used as a way to convert customary land to state land (e.g. Zambia)
- Investors in effect getting free access to land, i.e. not paying a purchase price or rent
- The company leasing the land pays the government and not the local community
- Deals are made with chiefs, without community members being consulted. In the worst cases, the chiefs use them for their own personal benefit whilst community members are disadvantaged.
- Total collapse of projects (especially jatropha projects) due to poor planning.

Poor practices in dealing with local communities during project initiation can result in the communities harbouring resentment of the projects. This discontent among local communities can have many detrimental long-term impacts on the emerging biofuel industry. As the situation in Dwangwa Malawi illustrates (see above), civil law cases can be involved, even many decades after the establishment of the project. In addition, dissatisfied local communities can create a direct threat to a project; for instance, arson attacks are a common occurrence in the South African forestry industry.

The concept of *free, prior, and informed consent* is becoming entrenched as the appropriate approach to land acquisition for projects (Franco 2014; Hall et al. 2015a), and global certification initiatives such as the Round Table on Sustainable Biomaterials (RSB) have established sets of social standards. However, if the criteria relating to these standards are not applied at the point of project implementation, it is often difficult or near impossible to correct this retrospectively.

Finding biofuel production models that both meet the needs of the industry (and investors) and are fair and equitable to local communities is paramount. In many cases this may involve setting up the correct ratio of large plantations to outgrowers, although the traditional concept of outgrowers is also being challenged and new and more innovative models have started to emerge.

5.4 Factors governing production models

The type of farming system that can be implemented is partly governed by the nature of the biofuel crop being grown (see above), the processing technologies used (see above), the scale of the processing facility (see above), the type of infrastructure needed, the national objectives for entering into biofuel production, and a multitude of other local issues (including land tenure regulations).

It is important to recognize that, in Africa, large-scale biofuel investments are supported by governments because of their development potential and not their climate change mitigation potential (von Maltitz and Stafford 2011). This means that the production models developed in Africa focus on socio-economic needs, such as job creation, rural development, and contribution to national economic development, and are not about GHG mitigation efficiency. The feedstock production models that are best suited to the African situation may, therefore, be very different from the models proposed in Europe or America. It is important to note that the climate change potential of biofuels is being challenged globally, with the result that they do not receive the same level of political support that they did a decade or two ago. This debate, however, is of lesser importance in the African context unless the export of biofuels is envisaged.

Concerns around food–fuel conflicts remain an important consideration in the region. Current project experience has, however, found no evidence that biofuels are having a negative food impact (von Maltitz et al. 2016).

5.5 Maximizing development benefits from biofuels

Given that biofuel development in Southern Africa is driven by rural development benefits rather than climate change benefits (see above), production models are developed to achieve these objectives. These models need to take into consideration potential food production impacts, and in at least some instances seem to do this.

At national level, sugar production has had major impacts on Southern African economies. Terry and Ogg (2016) suggest that the Swaziland sugar industry contributes 18 per cent of Swaziland's GDP, and Richardson (2010) reports that sugar contributes 4 per cent to Zambia's GDP and constitutes 10 per cent of Zambia's formal waged sector. Richardson (2010) also raises the concern, however, that many of the better-paid jobs are given to expats, so that their wages in effect leave the country. Sugarcane production has often been criticized for offering poorly paid labour (e.g. Richardson 2010). Mudombi et al. (2016), however, find that in sugarcane-growing areas there is less multidimensional poverty than in matched control areas.

In a Zambian case study, Richardson (2010) shows that the economic benefits from sugar production can be less than anticipated if inappropriate government policies are in place. He suggests that the Zambian sugar industry is being taxed at very low rates, but despite this concedes that a vast number of jobs have been created that pay above minimum wage levels. It is, however, suggested that other industries may be able to provide greater labour intensity in terms of agricultural production, hence impacting on more people. Underpinning Richardson's concerns seems to be the disproportionate power that the large sugar companies wield, and the fact that politicians are swayed by their influence to give overly generous business operation terms. Here, what are in effect private monopolies have been created (CUTS 2004).

The FDI, foreign donor, and World Bank support for large-scale agricultural projects is also coming under increased criticism. Much of this is to do with the level of local development achieved, as well as issues of equity.

Southern African biofuels need to provide national economic benefits, but it is the rural development benefits that should be the key driver for a Southern African country to support biofuel development. A few key aspects need to be considered regarding the rural development component.

- Return to land: are the economic benefits per unit of land better than those provided by alternative options?
- Return to labour: do local labourers, especially the lowest paid, get a better return from their labour working on the biofuel project than they would if they undertook the next best opportunity (subsistence farming in many cases)?
- Return to capital: is the biofuel project an appropriate investment strategy from a return-on-investment perspective?
- Revenue distribution: is the local community that made the land available getting a just share of the revenue stream from the project? Furthermore, is this revenue being justly distributed amongst community members?
- Distribution of benefits: are there groups in the community who lose out because of the introduction of the project and, if so, are they justly compensated for their loss?
- Social and environmental impact: is this a no-regrets development—i.e. will it have irreversible negative social or environmental consequences?

5.6 Large-scale versus small-scale approaches

Biofuel companies have two ways of obtaining biofuel feedstock: they can grow it themselves on their own farms; or they can purchase feedstock from third-party growers. The first option is commonly referred to as a 'concession scheme', since the land is often obtained via a concession (but could involve freehold tenure). These concessions typically range in size from hundreds to thousands of hectares and may also be referred to as commercial estates or plantations. The second production method can be referred to as a 'contract scheme', since production is normally under contract to the company (although growers can in some cases operate independently without contracts). Contract farming can involve large commercial farms (as in South Arica), but more typically involves smallholder farmers, referred to as outgrowers. Baumann (2000: 7) defines contract farming schemes as 'a system where a central processing or exporting unit purchases the harvests of independent farmers and the terms of the purchase are arranged in advance through contracts'.

Each model has its advantages and disadvantages in terms of rural development, equity, empowerment, and sustainability of the industry and the environment, and from a policy perspective regulations or incentives to influence the ratio of contract to concession farming may be an important policy decision (von Maltitz and Stafford 2011). Contract farming encourages the participation of both commercial and smallholder farmers in biofuel feedstock production. From a government or civil society perspective, contract farming may be favoured for equity and empowerment reasons. From an industry perspective, it means easier access to land and enables economies of scale through larger feedstock production. Contract farming may also help to build a positive relationship between the industry and surrounding communities. It could also be a way of building the necessary market while safeguarding staple food production and ensuring pro-poor growth. Smallholders are often motivated by the opportunity to utilize idle land (whether marginal or high quality) to generate additional income. In addition, the company typically provides a level of technical and financial support to contract farmers that is not available through the public sector. In most instances, establishing viable contract schemes requires the company to provide credit, timely supply of inputs, knowledge transfer, extension services, and/or market access. The system is open to abuse if not regulated, however, as companies often in effect hold a monopoly on the market. To create equitable bargaining power, communities need to form structures and may require the assistance of a neutral broker (e.g. a state department). Their rights can be secured through equitable long-term contracts that are developed in a participatory manner. Safeguards are often needed to ensure that companies maintain ethical engagement with their contract farmers, and this may well require state intervention and/or legislation. The use of third-party certification is an effective way of ensuring compliance.

Concession farming also has its benefits. First, it is a way in which industry can ensure control over feedstock availability. Since biofuel processing facilities are extremely expensive, especially in the case of bioethanol, companies often require security of supply before investing. Where private land ownership is an option, this can involve a simple but expensive land purchase. On areas of customary or state land, however, a more common option is through long-term leases, where the estate owner pays rent to the government. (Lease agreements tend to be with the state, and not directly with local communities.)

Possible implementation modalities for feedstock production

Using outgrowers or contract farmers in conjunction with, or as an alternative to, large-scale estate plantations is a common and well established mechanism to overcome some of the concerns around large-scale plantations. Advantages of this arrangement to both the buyers and outgrowers are summarized in Figure 4.

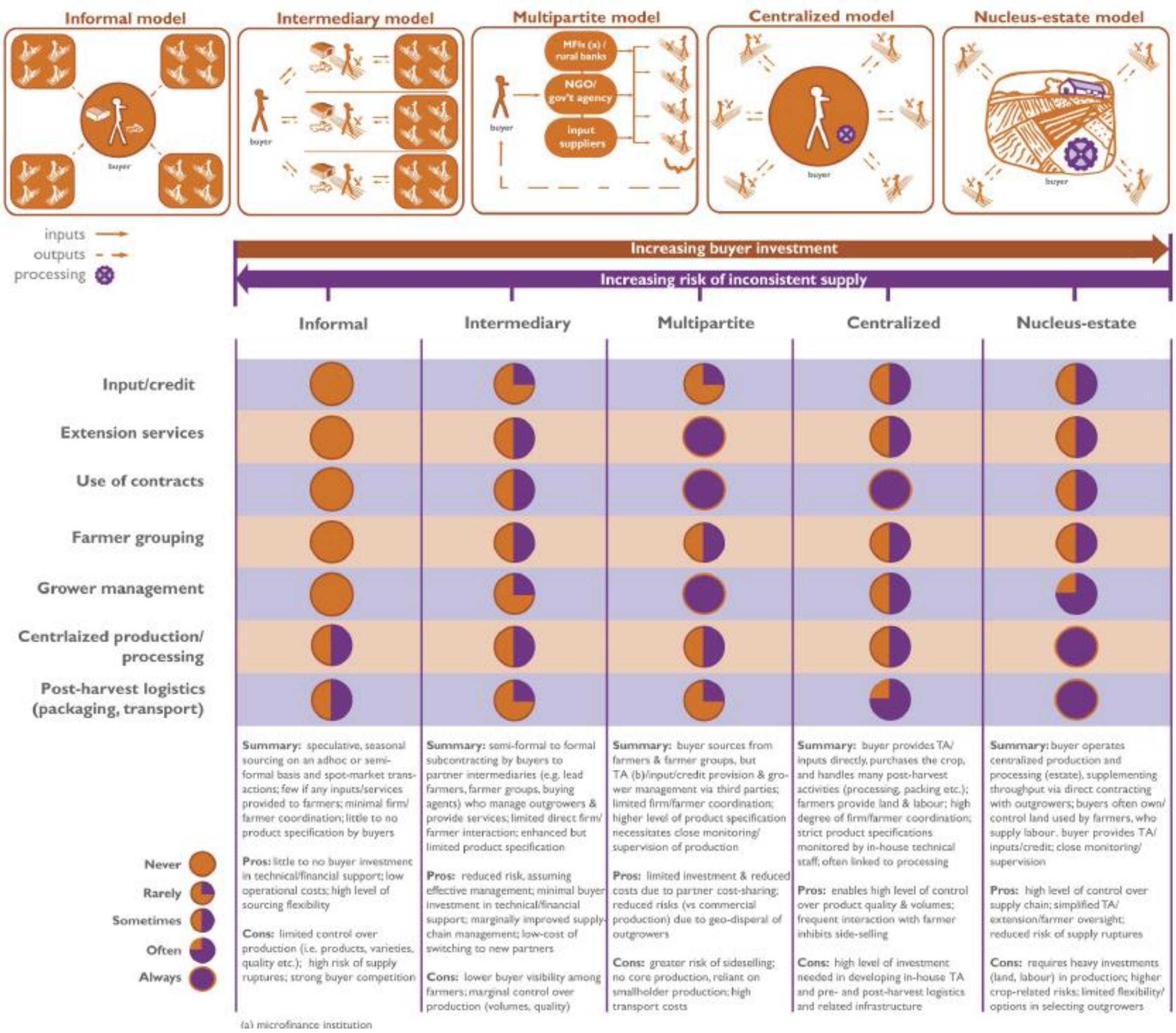
Figure 4: Major benefits of outgrower schemes as identified by TechnoServe and IFAD

For the Buyer:	For the Outgrower:
• Reduced capital investment in centralized production (land, infrastructure, equipment etc.) • For processors, enhanced control over sourcing (variety, quality control, timing, food safety, traceability) • Potential for improved product quality • Enhanced flexibility to target new market segments with specific qualitative specifications (e.g. fair trade, organic) • Diversifying production risks (e.g. crop disease) via smaller, geographically-diverse production areas • Greater flexibility in responding to market signals • Reduced labour costs (and conformity to labour laws) through subcontracting • Favourable public relations with government and the wider public • Potential for enhanced transactional efficiencies and reduced procurement costs via direct-sourcing linkages	• Improved access to credit for purchase of inputs, or direct provision of inputs by the buyer • Guaranteed access to new, higher-value markets (e.g. processing, export, niche) • Improved access to extension services and post-harvest technical assistance • Better access to new technical and management skills required to satisfy market requirements • Improved access to information and enhanced market transparency • Reduced fixed (e.g. equipment) and/or variable costs (e.g. inputs, transport) • Higher income due to increased yields and/or quality-related price premiums • Potential for higher farmgate prices via direct linkages to buyers

Source: TechnoServe and IFAD (2011).

TechnoServe (2011) suggests that there are a multitude of outgrower models, in which the higher the level of buyer investment, the lower the risk of inconsistency of feedstock supply. When looking at biofuel projects in the Southern African sub-region, jatropha-based projects have spanned the range of models, but in many cases are close to the informal and intermediary models in the left column of Table 1/the left side of Figure 5. This is because jatropha (high energy density, high storage durability; see Figure 3) can be grown by farmers with limited industry assistance. It can also be transported over large distances, which means that there is no need for a high concentration of growers surrounding a centralized estate. One key concern to investors relating to this model is that growers can sell their product to multiple buyers. In the case of Mali Investments in Zambia (Haywood et al. 2008), the company tried to prevent this by forcing growers to enter into complex and long-term legal agreements (this all collapsed when jatropha proved to be unprofitable due to low yields).

Figure 5: Different outgrower models as envisaged by TechnoServe and IFAD



Source: TechnoServe and IFAD (2011).

Sugarcane (for sugar) models in the region have tended to be centralized around a large industry-owned estate (low-energy-density, low-storage-potential crops; see Figure 3). Outgrowers in effect supplement the production from the estate, allowing the estate to have greater access to feedstock than would be possible simply from its own land. In effect, the estate typically has a monopoly on purchasing the farmers' yield, not only due to the nature of the agreements with the smallholder, but also, more importantly, because it is not economically viable for the smallholder to transport the feedstock to a more distant mill. In many cases with sugarcane, the smallholder projects are viable only because there is an irrigation scheme on the land. The terms of funding for the irrigation scheme may also lock the land users into specific production models.

Impacts of tenure on production models

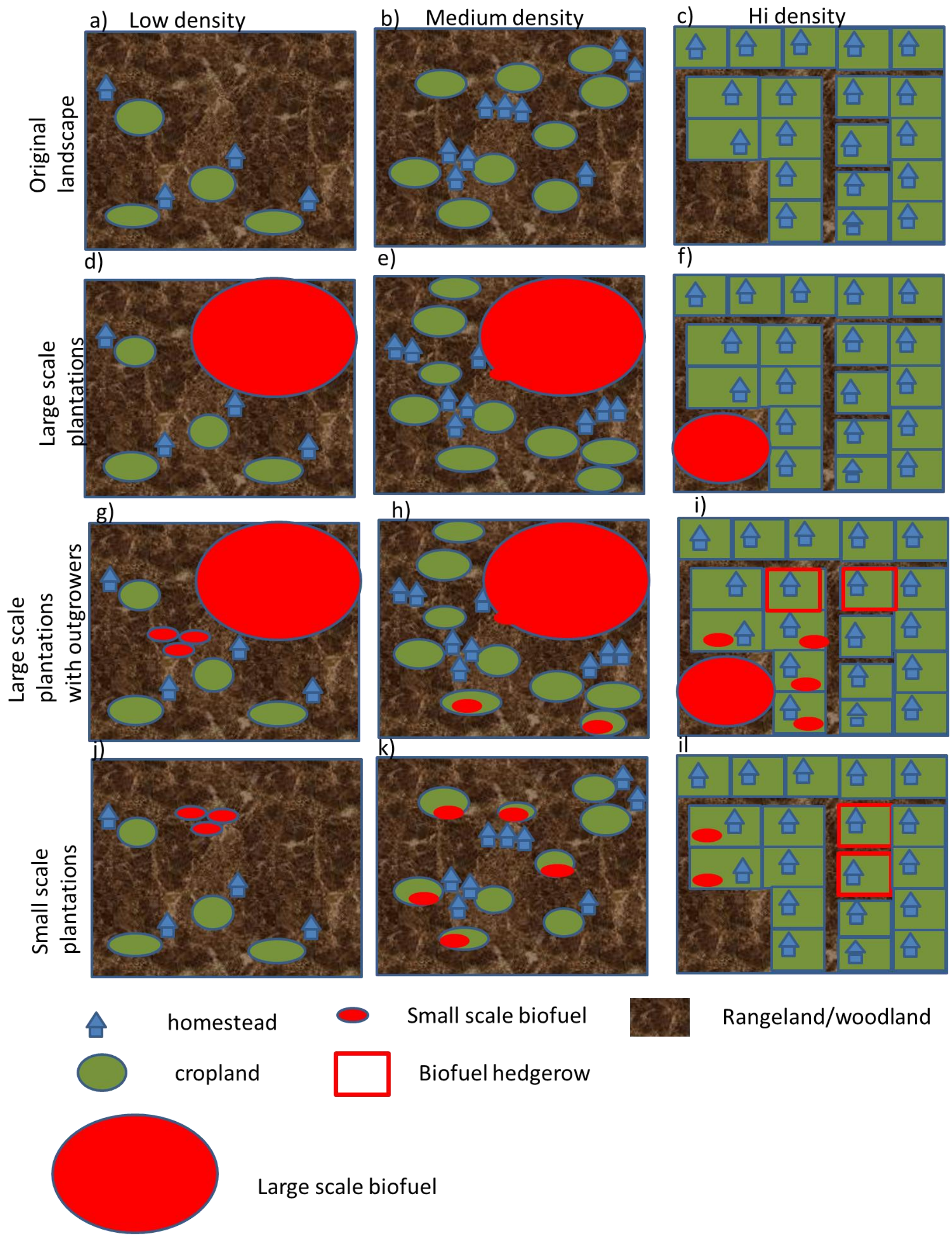
Underpinning most issues relating to biofuel expansion and the models that can be implemented in the sub-region is the issue of land access and the nature of current farming practices. With the exception of much of South Africa, state ownership of land dominates the region, local peasant farmers having access to land through customary mechanisms. Land that is under customary use can be accessed for large-scale projects only if it is moved from customary use to leasehold land that can be made available to developers. Rules for this are country-specific. In some cases, even if the land is theoretically allocated for development, in practice it may be currently used by peasant farmers for subsistence-type farming activities.

In Mozambique, a *Duet* is issued to developers that gives them long-term leasehold rights. In Zambia, customary land is converted to state land before being leased for development (see case study data for Zambia and Mozambique). As covered elsewhere in this paper, the way large-scale projects treat local community members is one of the biggest concerns around large-scale project development.

Most of African peasant farming is conducted on landholdings of just a few hectares. The farmers have customary tenure rights, but not true title deeds to the land. They therefore cannot use the land as collateral. In most cases, farmers farm first for subsistence purposes, selling only surplus for cash income. A number of crash crops, such as tobacco, tea, coffee, and cotton, may also be grown on surplus land. Farmers with surplus land can relatively easily convert some of it to biofuel production, but this may well impact on their food crop production.

The type of production model is to a large extent dependent on the existing human settlement density on the land (Figure 6). This will determine both the options available for the introduction of large-scale estates and those available for smallholder producers. In some areas, such as central Mozambique, it is relatively easy for farmers to expand their farms by clearing the surrounding woodlands. If they do not have existing use rights to the land, then permission might be required through the local chief or district officials. In other areas, including most of Malawi, all available farmland is already occupied and fully used. For local farmers to move from small-scale subsistence farming to larger-scale commercial farming may require a formalized process of land re-allocation.

Figure 6: Conceptual models of how population density leads to different options for biofuel production



Source: Modified from von Maltitz (2014).

In South Africa, it is in the 13 per cent of the national land area that makes up the former Bantustans that there is the largest potentially available area of land for biofuels. In many cases, subsistence farming has largely been abandoned, or is operating at a very low level. For individual farmers to grow biofuel on their individually allocated crop plots should be relatively easy, as they have the right to use their land as they wish. However, these allocations are typically very small, mostly only 1 ha or less. In a few situations the land holdings are slightly bigger (up to about 15 ha), as is the case with the smallholder sugarcane and forestry projects in Kwazulu-Natal. Where land is largely communal, the process of establishing a large-scale commercial project is highly complex. What is termed a back-to-back lease agreement must be entered into between the developer, the tribal authority, and the minister of land affairs. Given that most communities are quite large in terms of number of households, the process of negotiating an agreement can be lengthy. The forestry industry has been struggling for years to set up afforestation projects, with limited success.

The South African commercial farming sector is far less complicated. Individual farmers own relatively large private farms, where they have a large degree of autonomy over what they grow. They would be limited only by national legislation, including the biofuels strategy. This sector, however, has very limited land available for expansion beyond the land that is currently used for food crop production.

Where irrigation projects are involved, the process may be still more complicated, even if the land is to go to local community members, as large blocks need to be cleared. This may entail the displacement of existing users from the land. Historically, there have been cases where the political or financial elite, rather than existing land users, gained access to this new land.

5.7 Developing new and innovative farming models

For biofuel to succeed as a development crop, new institutional models are needed that will ensure that peasant farmers, workers, and other feedstock growers are not disadvantaged by the biofuel industry. A number of recent developments in the region are starting to highlight new and innovative approaches that might work in the future.

Big plantations that are socially responsible

Large estate plantations are an effective way for a company to ensure at least part of their feedstock production. This production model, more than any other, has received widespread criticism. However, with feedstocks like sugarcane where large and expensive mills are involved, investors need some guarantee around feedstock production and large plantations are the easy way to ensure this. Large plantation models can be greatly improved through the following mechanisms:

1. Ensure that free, informed, and prior consent (FPIC) is obtained from local communities.
2. Use an intermediary (NGO or government) with no vested interests, to ensure that communities are well informed of both opportunities and risks and able to express their concerns in a free manner.
3. Make sure that crops are fully tested and that their financial and technical sustainability is sound (to prevent the problems experienced with jatropha).
4. Ensure that all expectations of benefits are realistic.
5. Ensure that the principles of certification agencies (e.g. RSB) are adhered to right from the initial planning phase. Project set-up should be linked to a certification agency (e.g. RSB or Bonsucro).
6. Conduct environmental and social impact assessments.
7. Make sure that local residents have preferential access to job opportunities.
8. Make sure that labour rates are fair.
9. If individuals are relocated to make way for the development, ensure that compensation is fair and just.
10. The most contentious issue will relate to land ownership. The actual land users must gain real benefits from the project. Since in effect they bring land freely to the project, they should be given true ownership in the project, possibly as shareholders.

11. New models where the community members become owners or part-owners of the corporate plantation could also be considered. In essence, these community members are making land available to the company, so having part-ownership could be justifiable.

Community ownership of corporate plantations

For biofuel feedstocks, the scale of production is critical. For a feedstock such as sugarcane, where the harvested product must been processed as soon as possible and where transport distances need to be minimized, there is a need for consolidated large blocks of feedstock production. This is even more important if irrigation infrastructure is involved. There is no logical reason why these plantations cannot be owned and managed by the community.

The model used by SWADE in Swaziland is in fact a large plantation model (though still quite small compared with some industry estates), fully owned by the community. In this model, the community's land was handed back to the state and then transferred to a sugarcane growing company (a process that applies in many Southern African countries when land is allocated to investors). What is unique is that the company is fully owned by the original landholders. This model ensures that the plantation is large enough to be managed on a commercial basis with commercial managers, but ownership remains with the community.

A logical extension of this model would be to achieve a level of vertical integration, whereby the community also has a level of ownership in the mill. This would circumvent the accusation that mills extract high profits at the cost of growers.

Alternative models might be considered co-ownership approaches, where the community enters into a joint partnership with investors to set up a biofuel feedstock production plant. A key consideration in such models is how dividends are distributed. They would need to be linked directly to the individuals whose land becomes part of the plantation. Linking dividends through traditional authorities or local government structures is inappropriate due to a long history of rent-seeking by such structures. There are examples of chiefs having played this role effectively, but they are the exception.

The SWADE and related models, though appealing, are still in their infancy and are not without problems. In the Swaziland case, there is discontent over farmers having equal ownership despite contributing different amounts of land. There is also the concern that individuals have lost their land in perpetuity.

Community mobilization through group structures

A more common way of getting outgrowers to work together is for them to form large farming blocks (and hence achieve advantages of scale). These can take the form of trusts, cooperatives, or other legal entities. The degree to which individual farmers continue to farm their own land within this larger structure can vary substantially. At one extreme, farmers farm their own land and derive profits from their own harvest. At the opposite extreme, the land is farmed as a block and profits are shared in proportion to individuals' land holdings.

These farming arrangements tend to work best where the group arrangement focuses on ensuring scale benefits in sourcing inputs and securing the best prices from markets. They projects tend to perform badly if based on a model of shared work and shared profit, i.e. a communist model of cooperative farming.

The role of government in establishing institutional frameworks

The government can play a critical role in ensuring equity between the interests of biofuel growers and the biofuel processing facilities. Very little data are available from the emerging biofuel industries, as there is no production as yet, but lessons can be gleaned from the long-standing sugar industry. For instance, in Swaziland (and South Africa) there are set formulas as to how sugar revenue is distributed. Sugar is marketed by the sugar industry, the revenue being split in accordance with a formula between the miller operations and the sugarcane growers. This results in each getting a set percentage of the revenue. In effect, this means that the growers have a full stake in the overall sugar industry rather than simply selling their feedstock to the mills (who could then be making all the profit). In countries such as Zambia and Mozambique, the state does not play this equivalent role, and therefore it is potentially easier for the mills to use their monopolistic powers to exploit the growers.

The role of certification bodies

Certification (e.g. through Bonsucro for sugarcane or the RSB for biofuels) is a powerful mechanism for driving sustainability in the biofuel sector. It also removes the responsibility for monitoring performance against suitability standards from the government, which may have limited capability to do this (Guariguata et al. 2011; Vis et al. 2008; Zarrilli and Burnett 2008).

The roll of the mill / commercial estate and development agencies

The commercial estate and mill can provide extensive technical and other services to the farmers. In many cases, they can also provide bridging finance and access to cheaper inputs. In practice, the Southern African experience suggests that in most cases there is also some form of facilitating intermediary between the growers and the mill. In the case of Swaziland, the parastatal organization SWADE facilitates the setting-up of the grower companies as well as access to inputs and markets. It in effect forms a barrier between the growers and the sugar corporations. In the case of Dwangwa in Malawi, a trust funded by the growers has a similar function. A potential concern is that these in-between organizations place a heavy tax on the farmers' income, which may over time exceed the benefits they provide.

It is not clear whether the best models involve direct mill- (and/or estate-) to-farmer linkages or not. The monopolistic nature of mills is an issue of potential conflict and, unless the farmers have a sound mechanism for negotiating prices, it is possible that the mill will exploit them. Changing the ratios of small growers to the core estate, as well as ensuring that small growers operate through independent (cooperative) structures with high bargaining power can mitigate this risk.

The role of the state as a potential independent broker is critical. In addition, the state needs to put in place checks and balances to attract investment on the one hand and to ensure that community members are not exploited on the other.

Outgrower options for non-irrigated sugarcane

When sugarcane is not under irrigation, smallholders can grow the crop on their own land, rather than in large irrigated blocks. This is the case in much of the South African smallholder models (in KwaZulu Natal, but not the Nkomazi region). Some growers in the Dwangwa region in Malawi also use this model. Although yields are far lower, profit can be higher (Atkins 2015) .

The big problem with this mode of production is that unless farmers form some kind of community organization, such as a trust or cooperative, they have very limited individual bargaining power with the large mills. Also, inputs purchased in small quantities can be disproportionately expensive. From another perspective, the mills need a mechanism for scheduling the harvest, as they cannot deal with unpredictable volumes at the mill. Small mills (or simply crushing facilities) linked to dryland production might be feasible, but large mills based only on low-yielding rainfed cultivation are unlikely to be viable unless the area has a very high dryland yield potential.

Outgrower options for easily transportable crops

The principal factors that led to the wide promotion of jatropha as a biofuel crop were that it could be grown by small-scale farmers, potentially with limited impact on their other farming activities, and that it could be grown throughout a large region in relatively low density, then transported long distances to centralized processing facilities. Despite jatropha (in its current form) failing as a crop, some of the models attempted in the growing of jatropha might work for a more suitable crop. Von Maltitz et al. (2016), when reviewing the BERL project in Malawi, found that even with a very modest yield of 0.4 kg per tree, jatropha could be an economically attractive option for households and that it would out-perform a basket of food crops. At 0.8 kg per tree, the model as proposed by the BERL project would (if successful) provide households with revenue of US$100 per year, their only real costs being the labour involved (BERL estimates). Although this amount sounds trivial, it needs to be compared with the median benefits of US$14 from crop sales and US$111 (net) for all crops grown, including those used for home consumption (von Maltitz et al. 2016).

The BERL model advocated the planting of 600–800 jatropha trees on the farm boundary. It was assumed that these trees would largely be planted on previously unused land and that they would have no impact on adjacent crops—possibly a false assumption—so that farmers would still have a supplementary income. If the project could be extended to 200,000 farmers, it would produce sufficient oil for a 9 per cent jatropha blend in Malawi. Unfortunately, current jatropha yields are about an order of magnitude less than required.

Though it is hard to test, it seems plausible that it is jatropha as the feedstock, rather than the overall production model, that has failed. If improved jatropha or an alternative, similar crop is found, this model may still be appropriate. A secondary benefit of this model is that, since the jatropha is planted on disturbed land, it will help to conserve soil by preventing erosion and lead to carbon sequestration—a potential economic and environmental benefit.

Cassava might also be viable as a biofuel crop on small farms. Though not as energy-dense, nor durable in storage, as jatropha, it performs better than sugar in both these parameters. Projects in northern Mozambique have been using cassava for beer-making by using mobile processing plants. Cassava farmers could reportedly greatly increase their production, through both land expansion and better crop management practices, if there was a reliable market.

There seem to be a few common threads as to what needs to be in place for a smallholder biofuel crop to work. These are:

1. The crop needs to be easily stored and transported.
2. The crop must have a value per unit of land that is greater than the farmer can achieve from surplus food crops if it is grown on surplus land.
3. The crop must have a value considerably greater than the purchase price of food crops if it is grown on land that the farmer uses for food crops for home consumption.
4. The crop must have an operational market with relative price stability.

5. The crop must not compete strongly with food crops or the labour required for food crop production.

From an industry perspective, support for farmers from the biofuel industry is likely to be minimal in cases where it is not guaranteed a monopoly. For a crop such as sugarcane, the mill in effect holds a monopoly due to transport constraints. For easily transported crops, on the other hand, although companies have tried to enter into exclusive grower contracts with producers, these are probably non-enforceable if alternative markets exist. There might be circumstances in which they can have reasonable control because they are the only purchaser for a specific crop in the region. They might also loan input costs against crop delivery, but they will do this with caution, as they have limited options if growers default and sell their crop elsewhere. This contrasts with the sugar industry, where the growers have almost no ability to sell other than to a single industrial buyer. The fact that buyers can guarantee that the crop comes to them is what makes it attractive and profitable for the industry to support farmers.

Small farmers are also likely to become labour limited as soon as they exceed a certain size. They might be too small to mechanize, but too large to be able to farm with local labour alone.

6 Conclusions

For a biofuel industry to be viable, large volumes of relatively low-priced feedstock are a pre-requisite. This can be grown either on large dedicated estates or by smallholder farmers (referred to as outgrowers) or a combination of the two.

The most appropriate model for farming will be situation-specific and depend to a large degree on the nature of both the crop being grown and the size of the processing plant available. Large industry plantations have, however, historically earned themselves a bad reputation, especially in the way they treat local communities during their establishment phase. Any new large-scale projects will therefore have to be developed in a more socially responsible manner.

Finding plantation ownership models in which local communities maintain ownership in both the land and the large-scale plantation is an emerging mechanism to overcome some of the constraints of large-scale plantations. Once this has been achieved, a next logical step is to also give the community true ownership in the milling and processing side of the industry, as this will prevent the mills from exploiting the farmers.

For crops with high energy density and high storage potential, dispersed smallholder production models may be feasible. Such a model leads to a weaker coupling of the mill to the farmer, and potently reduces farmer support from the mill. It does, however, reduce monopolistic supply chains and potentially increase free market competition, whilst simultaneously opening up new commodity markets for the farmer.

Most African smallholder farmers have only a few hectares of land. For them to achieve large-scale feedstock production, and enjoy the benefits of large-scale farming, they must be enabled, in effect, to pool their land to form large-scale farming operations. There are multiple mechanisms through which this can be done, and it is the details and nuances of how ownership is determined and profit allocated that will ensure long-term sustainability. Creating models where communities have full or partial ownership in the milling of biofuel cops and the production of biofuels would seem a logical evolution of existing biofuel models, which could overcome many of the constraints of the traditional FDI models.

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