An Economic Evaluation of Soybean-Based Biodiesel Production on Commercial Farms in the Soybean-Producing Regions of KwaZulu-Natal: Some Preliminary Results

By

Sparks, GD; Ortmann, GF; and Lagrange, L

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GD Sparks[1], GF Ortmann[2] and L Lagrange[3]

Abstract

Global biofuel production has risen substantially in recent years, driven primarily by government support for biofuel industries. The stated motivations for these initiatives are numerous and have varied over time. Soybeans are the only field crop produced in sufficient quantities in KwaZulu-Natal (KZN) that the South African (SA) industrial biofuel strategy identifies as a potential biodiesel feedstock. Preliminary results from a mixed integer linear programming model support the notion of Funke et al. (2009), who contend that the incentives and commitments outlined by the industrial biofuel strategy are inadequate to both establish and sustain a domestic biodiesel industry.

Keywords: Industrial biofuels strategy; soybeans; biodiesel; KwaZulu-Natal; mixed integer linear programming

1. Introduction

Energy is essential to almost every aspect of both the economic and social development of South Africa (Winkler, 2005). Amigun *et al*. (2008a) note that Africa is endowed with significant quantities of both fossil and renewable energy resources. However, fossil energy resources are unevenly distributed on the African continent, with some 39 African countries being net importers of oil, some of which are among the poorest nations in the world (Mulugetta, 2008). World energy markets are indisputably dominated by the consumption of fossil fuels (Rosegrant *et al*., 2008). Elobeid & Tokgoz (2008: 918) attribute recent interests in biofuels to "environmental, economic, and geopolitical factors". Incentives to develop fuel technologies that utilise agriculturally-based materials as feedstock as a source of renewable energy have thus been attributed to: (i) high and volatile oil and fuel prices; (ii) a growing demand for energy; (iii) increased energy imports; (iv) uncertainties surrounding energy

[1] *Master's candidate in Agricultural Economics, School of Agricultural Sciences and Agribusiness, University of KwaZulu-Natal, Pietermaritzburg. E-mail: 205504870@ukzn.ac.za*
[2] *Professor of Agricultural Economics, School of Agricultural Sciences and Agribusiness, University of KwaZulu-Natal, Pietermaritzburg. Email: ortmann@ukzn.ac.za*
[3] *Senior Lecturer, School of Bioresources Engineering and Environmental Hydrology, University of KwaZulu-Natal, Pietermaritzburg. Email: lagrangel@ukzn.ac.za*

supplies; (v) the desire to establish energy self-reliance and alternatives to fossil fuels; (vi) an increased realization of the negative environmental consequences of fossil fuels; and (vii) a growing interest in supporting farms and rural communities through stronger agricultural markets (Haas *et al*., 2006; Marshall, 2007; Elobeid & Tokgoz, 2008; Rosegrant *et al*., 2008).

As a general conception, biofuels are obtained from natural sources, are renewable, and can recycle carbon dioxide from their combustion by means of photosynthesis (Escobar *et al*., 2008). Currently, biofuels are almost exclusively commercially produced by means of processing agricultural crops (Banse *et al*., 2008). These are referred to as first generation biofuels. Nevertheless, there have been considerable developments in the global production, production capacity, and trading volumes of biofuels in recent years (Banse *et al*., 2008; Meyer *et al*., 2008). This trend is expected to continue in the future (Wilson *et al*., 2008; Hoekman, 2009).

The perception that biofuels can contribute towards achieving solutions to numerous problems at once, ranging from the greenhouse effect, volatile oil prices, energy dependency, and rural development, has resulted in widespread acceptance and support among policy makers, scientists, environmentalists, agricultural entrepreneurs, and the general public alike (Russi, 2008). However, Herndon (2008: 403) suggests that the combination of market-induced and policy-induced factors relating to biofuel expansion have created a "perfect storm" causing dramatic shocks to essentially every crop and livestock producer, and agribusiness. Anderson *et al*. (2008) are of a very similar view. Accordingly, Hochman *et al*. (2008) suggest that perhaps no other recent economic development has more significant potential to reshape agriculture and farm policy than the emergence of a large and expanding biofuel industry.

Despite African countries, specifically those in Sub-Saharan Africa, currently being regarded as an unexploited resource for biofuel development (Amigun *et al*., 2008a; Mulugetta, 2008), there has been limited research conducted on the feasibility and potential impacts of an expanding global biofuel industry on domestic agricultural commodity markets from a South African (SA) standpoint (Amigun *et al*., 2008a; Meyer *et al*., 2008; Funke *et al*., 2009). Subsequently, the KwaZulu-Natal Department of Agriculture, Environmental Affairs and Rural Development (KZNDAEARD) has expressed interest and commissioned research to analyse the economic feasibility of domestic on-farm biodiesel production. The objectives of this article, therefore, are to present some *preliminary* results on the economic feasibility of on-farm soybean-based biodiesel production on commercial crop farms in the historically high soybean regions of KwaZulu-Natal (KZN). Section 2 briefly explores some global trends in biofuel policy initiatives and section 3 evaluates the SA government's biofuel policy stance. The baseline model specification and preliminary results are presented in the later sections of this article, followed by some conclusions.

2. Biofuel Policy Considerations

Rajagopal & Zilberman (2007) note that there has been an extensive history of dependence of alternative energy technologies on sustained governmental support in order to become competitive with fossil fuels in the marketplace. Biofuels are no exception, with government intervention in bioethanol markets dating back to as early as 1978 in the United States (U.S.) (Tyner, 2007), in the form of subsidies, federally-funded research, and quantity mandates (Khanna *et al.*, 2008). Similarly, Brazil, now a well-established producer and consumer of bioethanol, promoted the development of its bioethanol industry through the National Alcohol Program (PROALCOOL), which was launched during the mid-1970s (Elobeid & Tokgoz, 2008). Sustained governmental support, therefore, has undoubtedly been an essential feature of the development of the biofuel industries in many of the present global market leaders in biofuel production (Meyer *et al*., 2008).

The stated motivations for these legislative initiatives are numerous and have varied over time (Tyner, 2007). Accordingly, an abundance of current biofuel policy initiatives exist (Rajagopal & Zilberman, 2007; de Gorter & Just, 2008), and trends indicate that they will continue to do so in the future (Rajagopal & Zilberman, 2007). However, the rapid growth of biofuel production in recent years has stimulated considerable and growing deliberations over how policy changes will continue to influence this emerging industry, and associated spillover effects into other markets (Elobeid & Tokgoz, 2008). The importance of the correct set of biofuel policies has been noted by numerous authors, with the vast majority of published applications focusing specifically on the U.S. bioethanol industry (Gardner & Tyner, 2007), very recent examples of which include de Gorter & Just (2009a, 2009b) and de Gorter *et al*. (2009). Similarly, de Gorter & Just (2008) note that the potential misalignment of policy effects and stated objectives can pose serious difficulties for policy analysis, and emphasise the importance of the fundamental underlying economics of these policies.

Nevertheless, the most widely utilised biofuel and related policies on a global scale are excise tax credits, renewable fuel standards and mandatory blends.

3. South African Biofuel Policy Initiatives and Proposed Targets

The SA government has committed to comply with the framework of the Renewable Energy White Paper, which stipulates the production of renewable energy of 10 000 GWh (equivalent to 0.8Mtoe) [4] to be achieved by 2013 (DME, 2003), a portion of which has to come from the production of biofuels (Meyer *et al*., 2008). This is approximately four percent of the projected electricity demand for 2013 (DME, 2003). Currently, however, renewable energy contributes relatively little to energy levels in South Africa (DME, 2003; Winkler, 2005).

A brief overview of the current SA biofuels industrial strategy is provided by Funke *et al*. (2009). Key aspects include the targeted 2% penetration level of biofuels in the national liquid fuel supply, equivalent to 400 million litres per annum, by 2013 (DME, 2007). Furthermore, the strategy recommends blending requirements of 2% and 8% for biodiesel and bioethanol, respectively. These targets were proposed to be maintained until 2020. Additionally, the industrial strategy recommends that: (1) the current biodiesel fuel levy exemption be increased from 40 to 50%; (2) the small-scale producer's threshold be raised from 300 000 to 1.2 million litres per annum (the SA Revenue Service (SARS) permits a 100 percent exemption for these small producers); and (3) a 100% fuel levy exemption for bioethanol be introduced (DME, 2007).

The DME (2007) contend that these goals can be achieved without jeopardising food security. They estimate further that only 1.4% of arable land in South Africa would be required and approximately 25 000 jobs would be created in meeting these objectives. Although job creation is a key focus of the revised strategy, these estimates may well be optimistic. For example, Gohin (2008) contends that only 43 000 jobs will be created by meeting the EU's biofuel target of 5.75 percent of transport fuel by 2010. Interestingly, in the U.S. "small bioethanol and biodiesel producers" constitute plants producing less than 60

[4] **GWh** (Gigawatt hour) is an energy unit in which electricity consumption is measured. (1 GWh = 3600 GJ (Gigajoule) (Joule is unit of energy)) (DME, 2003).
Mtoe (Million tons of oil equivalent) is a universal unit of comparison in which all energy can be measured. (1 Toe = 42 GJ = 0.042 TJ = 0.012 GWh) (DME, 2003).

million gallons per annum. These producers are eligible for small producer excise tax credits, with a maximum credit of up to $1.5 million per annum (Eidman, 2007).

However, there still appears to be a lack of a clear and comprehensive policy framework for the development of a SA biofuels industry, as none of the above *proposed initiatives* have been implemented to date. There are also concerns among stakeholders that government policy is taking too long to formulate, compounding existing uncertainty in the industry. These concerns appear to be further aggravated by the fact that South Africa's commitment to the framework of the Renewable Energy White Paper is not binding. Therefore, if the targets for 2013 were not reached the government could simply "shift the goal posts" to a later target date. Thus, South Africa's biodiesel market is presently characterised by several small- and medium-scale producers (Amigun *et al*., 2008b), which may be of direct consequence to existing biofuel policy given that the most support currently exists for producers operating below the small-scale producer threshold of 300 000 litres per annum.

Importantly, Funke *et al*. (2009) contend that the incentives and commitments as proposed by the SA biofuels industrial strategy (DME, 2007) are inadequate to both establish and sustain a domestic biofuel industry. With specific reference to potential SA biodiesel production, Funke *et al*. (2009: 241) point out that "revised and more clearly defined strategies are required to stimulate the set up of a biodiesel industry that can eventually lead to the successful obtainment of the objectives as set out in the biofuel strategy". These authors, however, did not quantify or propose possible policy measures.

4. The Model

The SA biofuels industrial strategy identifies three primary field crops to be considered as feedstocks for domestic biodiesel production, namely sunflower, canola and soybeans (DME, 2007: 3). However, since sunflower and canola are grown in relatively insignificant quantities in KZN (Whitehead, 2010), soybeans are the only realistic potential biodiesel feedstock that is currently grown in large quantities in the KZN region. Subsequently, a linear programming model of a typical commercial crop farm in the historically high soybean-producing regions of KZN was developed. More specifically, these high soybean-producing areas include the Bergville/Winterton, Newcastle/Normandine, Vryheid and Midlands regions of KZN (Whitehead, 2010) (see Appendix A). Importantly, these areas also hold the greatest potential for future expansion in soybean production in the KZN province.

From a crop farming perspective, Brink & McCarl (1978: 259) suggest that crop-planning models can be used for at least three purposes: (i) to aid farmers in planning their land allocations; (ii) to help farmers budget returns to investments; and (iii) to assist policy makers predict farmer responses to policy decisions. A linear programming baseline model was developed using 10 years of yield, variable cost and product price data from COMBUD field crop budgets, which are compiled annually by the KZNDAEARD. The COMBUD field crop budgets are a widely accepted source of data, and Whitehead (2010) suggests that these budgets adequately reflect the average production circumstances faced by crop farmers in the KZN region.

The 10 years of COMBUD production data used in this analysis include nine years of historical data (2000/01-2008/09), as well as the current (2009/10) planting season. All nominal production data were adjusted to a real 2008 basis, using the consumer price index. The COMBUD field crop budgets cater for both dryland and irrigation land categories. Crops considered in the baseline model include soybeans, maize, dry beans, sorghum, groundnuts, and irrigated winter wheat. The baseline model was developed to incorporate a discrete choice between no-till and conventional tillage practices, reflecting a realistic choice facing all crop farmers in the KZN region (Whitehead, 2010).

The presence of risk and uncertainty are typical characteristics of all farming enterprises (Hazell, 1982; Hazell & Norton, 1986; Stockil & Ortmann, 1997). While most early studies attempting to account for risk made use of quadratic programming techniques, as developed by Markowitz (1952, 1959), Hazell (1971) and Hazell & Scandizzo (1974) recommend the use of linearization techniques that allow conventional linear programming to be utilised. In this regard, McCarl & Tice (1982: 588) contend that their approach "works well for risk programming and provides superb computational advantages for large problems". For these significant benefits, as was the rationale for Ortmann (1988) and Ortmann & Nieuwoudt (1987) the methodology for incorporating risk in linear programming models first proposed by Hazell (1971), and later refined by Hazell & Scandizzo (1974), has been adopted in this study.

Therefore, in this analysis possible risk-averse behaviour of farmers was catered for by maximising the criterion $E - \theta \sigma$, where E is expected income, θ is an aggregate risk-aversion parameter, and σ is the standard deviation of income (Baumol, 1963; Hazell & Norton, 1986: 91-93). Thus, the objective function treats risk (σ) as a cost that is weighted by the risk aversion coefficient (θ). The larger the θ-value, the greater the weight that is attached to risk and the more diversified the resulting farm plan is expected to be. This technique has been used in both sector (Simmons & Pomareda, 1975; Nieuwoudt *et al*., 1976; Hazell & Scandizzo, 1977; Ortmann, 1988; Ortmann & Nieuwoudt, 1987) and farm level studies (Brink & McCarl, 1978; Brandao *et al*., 1984; Lyne *et al*., 1991).

Using a combination of the approaches used by the above studies, the basic inclusion of risk as a cost factor can thus be illustrated as follows:

$$\text{Max } L = [P'YX - C'X - \theta (X'\Omega X)^{1/2}] \qquad (1)$$

where P'YX is crop income, P being a vector of product prices, Y a diagonal matrix of yields per hectare, and X a vector of crop areas; C'X is total market production costs, C representing a vector of production costs per hectare; θ is a famer's risk aversion coefficient; Ω is a variance-covariance matrix of gross margins per hectare; and $(X'\Omega X)$ represents variance in gross margin.

The standard deviation estimate can therefore be calculated in the following manner:

$$\text{Est } (X'\Omega X)^{1/2} = \frac{\sqrt{\Delta}}{T} \qquad (2)$$

where $\Delta = T \Pi / 2(T - 1)$, which is regarded as a "correction factor to convert the square of the mean absolute deviation to an estimate of the population variance (assuming the population is normally distributed)" (Simmons & Pomareda, 1975: 473). In the above specification, T is the total number of periods considered, and Π is the mathematical constant.

When using cropping models which incorporate risk by maximising the criterion $E - \theta \sigma$, Ortmann (1988) and Ortmann & Nieuwoudt (1987) note that the sensitivity of the model can be determined by testing various values of θ in successive optimisations. Thus, θ in equation (1) was varied to determine the best simulation of present cropping patterns and land rental rates in the historically high soybean-producing regions of KZN. The fact that θ values can be easily manipulated when using this criterion provides the modeller with a relative degree of flexibility. Thus, Ortmann (1988) and Ortmann & Nieuwoudt (1987) conclude that the θ coefficient can essentially be regarded as a fine-tuning device, with θ also capturing other effects, including data errors and model misspecifications (Hazell, 1982). Subsequently, no attempt will be made to draw conclusions about the level of risk-aversion among commercial crop farmers in the historically high soybean-producing regions of KZN.

Generally, all optimisations performed comparably in terms of predicting cropping behaviour, with the dominant crops being maize, soybeans and irrigated winter wheat – which are consistent with actual observed cropping behaviour in these regions (Whitehead, 2010). However, the model where $\theta = 2$ outperformed the others in terms of simulating observed rental rates for cropland in these regions. This was estimated to be 4.2%, which broadly conforms with other local studies (Nieuwoudt, 1980; Poray, 1983; Ortmann, 1987). Interestingly, this estimate is comparable to recent average cash rental rates of cropland observed in the U.S. Cornbelt region (USDA, 2009).

Hence, $\theta = 2$ was used as the basis to develop a mixed integer linear programming model, comprising approximately 50 rows by 70 columns, in order to analyse the economic feasibility of soybean-based biodiesel production on commercial crop farms in regions of KZN with historically high soybean production and significant cropping potential for future expansion of soybeans. Interestingly, Nieuwoudt *et al*. (1976) utilised the identical value of θ when they modelled peanut production in the USA.

Data on the associated costs of purchasing, installing and operating various capacities and qualities of both oil extrusion and batch processing biodiesel plants were obtained from numerous domestic and international technology suppliers. The economic evaluation of batch processing biodiesel plants is, therefore, an exploration of the recommendations of Amigun *et al*. (2008a), who postulate that the comparatively lower capital requirements (relative to continuous flow biodiesel plants), as well as the ability to regulate production within demand results in batch processors being well suited to small-scale biodiesel production operations, and thus to the African continent. Moreover, these authors point out that lower capital outlays may be a means of combating risks in biodiesel industries in the event that government energy policies are both uncertain and unpredictable. Against a backdrop of recent criticisms of the SA biofuels industrial strategy and limited local research, an analysis of batch biodiesel processors' appropriateness in the KZN region is well justified.

In an effort to remove bias, quotations received from six different technology suppliers were used to average capital expenditure cost estimates for two representative oil extrusion plants of different capacities, yet comparable qualities. Similarly, quotations from six technology suppliers were used to estimate average capital expenditure costs for five batch processing biodiesel plants of differing quality and capacity. Biodiesel plants were subsequently classified into broad quality groups, “high-tech” and “low-tech”, based on the composition and longevity of their respective components. Hence, estimates of the associated capital costs for the biodiesel processing plants are believed to be relatively more representative of the current SA industry than recent studies such as Nolte (2007), who utilised only one international technology supplier.

Fixed costs for the respective plants were annualised using the standard capital recovery approach (Gittinger, 1982; Monke & Pearson, 1989), assuming a real discount rate of five percent, zero salvage value, and an economic life of 15 years for the oil extrusion plants and “high-tech” biodiesel plants. Similarly, an economic life of five and 20 years were assumed for “low-tech” biodiesel plants and buildings, respectively. Annual capacities were based on the assumption of a six hour working day, for 240 days per annum.

There appears to be consensus among market participants, technology suppliers and industry specialists that extrusion costs of plant oil are in the region of R 250.00 and R 300.00/ ton. A similar conclusion was reached by Nolte (2007). However, the relevant parties consulted indicate that it is important to account for additional variable costs such as transport and storage, which increase variable costs quite considerably. Thus, the variable (operating) cost per litre of soybean oil was assumed to be R 3.75 in the baseline potential on-farm biodiesel production model. Similarly, the average variable cost to produce a litre of biodiesel was assumed to be R 2.00, comprising primarily of chemical costs. Importantly, these are believed to be relatively conservative estimates of the associated production costs for the respective production processes. Table 1 provides a summary of the baseline assumptions regarding capacity, annual fixed costs and variable (operating costs) for the respective oil extrusion and batch processing biodiesel plants.

Table 1: Summary of Key Plant Assumptions in the Baseline Model

	Oil Extrusion Plant 1	Oil Extrusion Plant 2	Biodiesel Plant 1 (Low-Tech)	Biodiesel Plant 2 (Low-Tech)	Biodiesel Plant 3 (High-Tech)	Biodiesel Plant 4 (High-Tech)	Biodiesel Plant 5 (High-Tech)
Annual Capacity (Litres)	90 720	259 200	48 000	96 000	360 000	960 000	1 920 000
Annualised Fixed Cost (Rand)	59428	158475	21656	36752	61309	108099	187966
Variable Cost / Litre Product (Rand)	3.75	3.75	2	2	2	2	2

The DME (2006: 109) suggests that one ton of soybean produces 171.4 litres of biodiesel, with additional by-products being 0.680 tons of soybean oilcake and 0.215 tons of glycerine. These figures appear to be based on the assumption that soybeans have an 18 percent oil content (Rajagopal & Zilberman, 2007: 102), and approximately a 95 percent conversion rate efficiency factor from soybean oil to biodiesel. The oil content and efficiency factor assumptions, as proposed by the DME (2006), may not be unrealistic, but they may be overly optimistic as some industry participants indicate that using traditional oil extrusion technology, a comparatively lower yield of approximately 120 litres of soybean oil per ton of soybeans can be expected, as roughly six percent of the oil remains in the soybean oilcake (Bullock, 2010; Fichart, 2010). Nevertheless, in order to be consistent with the apparent thinking of current SA policy makers conversion ratios for soybean-based biodiesel and associated by-products used in this analysis are based on those proposed by the draft National Biofuels Strategy (DME, 2006). These conversion ratios were converted to a tons per litre basis (see Table 2).

There is broad consensus that the sale and/or productive use of by-products contribute significantly to the economic viability and competitiveness of biodiesel plants (Amigun *et al.*, 2008b). Moreover, it is believed that the relatively high market value of soybean oilcake in particular may result in soybeans having the greatest potential as a first generation biodiesel feedstock (Bender, 1999; Meyer *et al.*, 2008). However, market prices of soybean oilcake in South Africa are highly volatile, compounded by the fact that the country has historically been a net importer of this commodity (Funke *et al.*, 2009). Accordingly, a similar situation exists for the SA soybean oil market. The Bureau for Food and Agricultural Policy (BFAP) model simulated prices for the 2009/10 production season of approximately R3300/ton and R8556/ton for soybean oilcake and soybean oil, respectively (Funke, 2010). This translates to a price of approximately R7.90/litre of soybean oil. Thus, given the scarcity of sufficient spans of time-series data for these commodities, particularly soybean oil, these prices were assumed in the baseline on-farm biodiesel production model. By comparison, industry participants and technology suppliers suggest that under current (2009/10) market conditions, biodiesel sells on average between R 6.50 and R6.60 per litre. The BFAP model predicts similar biodiesel prices (Funke, 2010), lending more credibility to previous price estimates. Thus, a biodiesel selling price of R 6.55 per litre was assumed in the baseline on-farm biodiesel production model.

Internationally, the crude glycerine by-product currently has a very limited market (Eidman, 2007). The same appears to be true in the SA context, where local industry participants and technology suppliers report that under current (2009/10) market conditions crude glycerine typically sells for approximately R1.00 per kilogram. An additional novel feature of this model was the allowance made for the possible on-farm use of biodiesel for the planting/harvesting requirements of the respective field crops. Key features of the baseline potential on-farm biodiesel production model are summarised in the form of a simplified linear programming matrix (see Table 2).

Table 2: A Partial Mini-Tableau of the Baseline Model

	Soybeans			Oil-Extrusion		Biodiesel		Sell	Sell	Sell	Sell	Use	Buy	RHS
	Dryland	Irrigated		Plant 1		Plant 2								
	Soygrow	Soygrow	Soysell	GIN	Operation	GIN	Operation	Soy oil	Biodiesel	Oilcake	Glycerine	Biodiesel	Diesel	
	(ha)	(ha)	(ton)		(litre)		(litre)	(litre)	(litre)	(ton)	(ton)	(litre)	(litre)	
Dryland (ha)	1													L 220
Irrigation (ha)		1												L 220
Transfer (ton)	-2.08	-3.5	1		0.00556									L 0
OP1 capacity (litre)				-90720	1									L 0
BP1 capacity (litre)						-48000	1							L 0
Soy oil (litre)					-1		1	1						L 0
Conversion (litre)							-0.95		1			1		L 0
Oilcake (ton)					-0.00378					1				L 0
Glycerine (ton)							-0.00125				1			L 0
Dieseluse (litre)	20	35										-1	-1	L 0
Objective	-3465	-5456	2880	-59428	-3.75	-21656	-2.00	7.90	6.55	3300	1000		6.69	MAX!

5. Modelling Results

The baseline model results reflect the current situation facing commercial crop farmers in the historically high soybean-producing regions of KZN for the 2009/10 production season, based on the macroeconomic assumptions and optimistic conversion ratios as presented in the previous section. Table 3 provides a summary of the key solution variables for the baseline optimisation, with θ = 2.

In the last decade commercial crop farmers in the historically high soybean-producing regions of KZN have moved progressively away from conventional tillage practices, in favour of zero or minimum tillage (Whitehead, 2010), as reflected in the baseline model optimization. However, some farmers in these areas may still have a preference for conventional tillage systems. Additionally, the dominant crops planted in these regions of the KZN province have consistently been maize, soybeans and irrigated winter wheat, again reflected in the baseline model optimization. Dry beans are planted to a lesser extent by some farmers in the soybean-producing regions of KZN, particularly the Bergville/Winterton area, but probably not on a consistent or annual basis. Dry beans, however, are traditionally a more common means to diversify cropping enterprises in the KZN region than sorghum and/or groundnuts (Whitehead, 2010).

Table 3: Optimistic Baseline Results for the 2009/10 Production Season

Cropping Behaviour	Dryland	Irrigation		**Investment Behaviour**	
Tillage Practice				**Oil Extrusion**	
Conventional	No	No		Plant 1	No
No-Till	Yes	Yes		Plant 2	No
Summer Crops					
Soybean (ha)	70	70		Sell Soybean Oil (litres)	0
Maize (ha)	140	140		Sell Soybean Oilcake (tons)	0
Dry Beans (ha)	10	10			
Sorghum (ha)	0	0		**Biodiesel**	
Groundnuts (ha)	0	0		Plant 1 (Low-Tech)	No
Total (ha)	220	220		Plant 2 (Low-Tech)	No
Winter Crops				Plant 3 (High-Tech)	No
Wheat (ha)	0	70		Plant 4 (High-Tech)	No
Total (ha)	0	70		Plant 5 (High-Tech)	No
				Sell Biodiesel (litres)	0
Objective Function Value	467 113			Sell Glycerine (tons)	0

As far as simulated potential farmer investment behaviour is concerned, under the baseline assumptions no oil extrusion or combination of oil extrusion and biodiesel plants are drawn into the optimum solution for an individual commercial crop farm in these regions. However, it is important to point out that this solution is highly sensitive to both the soybean oil price and soybean oilcake price. For example, in the event that the price of soybean oil increases to R8.50/litre or the soybean oilcake price increases to R3400/ton the smallest oil extrusion plant (Plant 1) is drawn into the solution. Accordingly, both of these by-products are sold, as presented in Table 4.

Table 4: Optimistic Baseline Results, assuming Increased Soybean Oil (R8.50/litre) and Soybean Oilcake Prices (R3400/ton)

Oil Extrusion		**Biodiesel**	
Plant 1	Yes (1)	Plant 1 (Low-Tech)	No
Plant 2	No	Plant 2 (Low-Tech)	No
		Plant 3 (High-Tech)	No
		Plant 4 (High-Tech)	No
		Plant 5 (High-Tech)	No
Sell Soybean Oil (litres)	70308	Sell Biodiesel (litres)	0
Sell Soybean Oilcake (tons)	266	Sell Glycerine (tons)	0
Objective Function Value	519 760		

The fact that biodiesel is not produced under either of these scenarios is not surprising, given that soybean oil is currently a higher-value product. Moreover, net variable costs per litre are comparatively lower than those of biodiesel production. This clearly emphasises the need for intervention should the SA government realistically wish to pursue domestic soybean-based biodiesel production. Furthermore, given that the markets for both soybean oil and soybean oilcake are highly volatile, and the sensitivity of the baseline model to these two commodity prices, which are closely related, the observed trend of individual crop farmers (not only in the KZN region) typically not establishing oil extrusion plants, let alone soybean-based biodiesel plants, may reflect general preferences in avoiding these relatively riskier enterprises (Funke, 2010; Hislop, 2010).

Nevertheless, in an attempt to quantify the level of government intervention necessary to draw biodiesel production into the optimum linear programming solution for the 2009/10 production season, the original baseline price assumptions are maintained. This may not be overly unrealistic given that South Africa is a net importer of both soybean oil and soybean oilcake. As such, their respective prices are already likely to be relatively close to import parity levels for the current season. Thus, successive optimisations of the baseline model with incremental increases in the biodiesel price were analysed to establish the minimum biodiesel price required to force biodiesel production into the solution. Table 5 presents a summary of these successive optimisations using the optimistic soybean oil conversion ratios.

Table 5: Optimistic Baseline Results under Various Farm-Level Biodiesel Prices, assuming Soybean Oil = R7.90/litre and Soybean Oilcake = R3300/ton

Investment Behaviour							
Biodiesel Price (R/litre)	6.55	7.55	8.55	9.55	9.90	10.55	11.00
	(Baseline)						
Oil Extrusion							
Plant 1	No	No	No	No	Yes (1)	Yes (1)	Yes (1)
Plant 2	No	No	No	No	No	No	Yes (7)
Sell Soybean Oil (litres)	0	0	0	0	0	0	0
Sell Soybean Oilcake (tons)	0	0	0	0	266	343	7197
Biodiesel							
Plant 1 (Low-Tech)	No	No	No	No	No	No	No
Plant 2 (Low-Tech)	No	No	No	No	Yes	Yes	No
Plant 3 (High-Tech)	No	No	No	No	No	No	No
Plant 4 (High-Tech)	No	No	No	No	No	No	No
Plant 5 (High-Tech)	No	No	No	No	No	No	Yes (1)
Sell Biodiesel (litres)	0	0	0	0	66793	86184	1809864
Sell Glycerine (tons)	0	0	0	0	88	114	2390
Buy Soybean (tons)	0	0	0	0	0	113	10193
Objective Function Value	467 113	467 113	467 113	467 113	467 653	516 598	562 092

Given the underlying assumptions in the baseline model, the minimum biodiesel price necessary for biodiesel production to be drawn into the optimum solution is approximately R9.90/litre. Subsidisation of the biodiesel price up to the soybean oil price (R7.90/litre) would subsequently be insufficient for farmers in the historically high soybean-producing areas of KZN to establish and operate a batch processing biodiesel plant. Therefore, these preliminary results provide evidence that supports the notion of Funke *et al*. (2009), who contend that the incentives and commitments outlined by the SA biofuels industrial strategy (DME, 2007) are inadequate to both establish and sustain a domestic biodiesel industry.

At a biodiesel price of R10.55/litre on-farm soybean-based biodiesel production in these areas of KZN is so viable that it actually warrants farmers buying in soybeans to supplement their own production (as depicted by increased sales of all by-products and subsequent higher objective function value). In both these scenarios the optimum solution utilises a combination of the smallest oil extrusion plant (Plant 1) and the largest Low-Tech biodiesel plant (Plant 2). The ability of this model to establish such optimum combinations is envisioned to assist both policy makers and technology suppliers in promoting the "most viable" plants of a given capacity and quality. Interestingly, the minimum biodiesel price required to draw in the High-Tech biodiesel plants into the optimum solution is R11.00/litre. This scenario uses a combination of one small oil extrusion plant (Plant 1), seven large oil extrusion plants (Plant 2) and the largest High-Tech biodiesel plant (Plant 5). This solution is highly dependent on buying in soybeans (10193 tons) and contributes relatively little to the objective function value. Not surprisingly, however, at high biodiesel prices no biodiesel is used on-farm for the planting/harvesting activities because the opportunity cost of using biodiesel is relatively high.

When using the less optimistic conversion ratios, as recommended by industry role players and technology suppliers, the situation is somewhat different. As anticipated, the level of government intervention necessary to stimulate on-farm biodiesel production in the soybean producing regions of KZN is markedly higher. Table 6 presents a summary of the successive optimisations, again using incrementally higher biodiesel prices, but assuming the less optimistic conversion ratios of 120 litres of oil per ton of soybeans.

Under these less optimistic assumptions, the minimum biodiesel price necessary for biodiesel production to be drawn into the optimum solution is approximately R11.47/litre. This is R1.57/litre higher than under the optimistic scenario. Interestingly, however, the optimum solution combines both the smallest oil extrusion (Plant 1) and smallest Low-Tech biodiesel (Plant 1) plants. This is different from the optimistic scenario. Subsequently, the quantity of biodiesel produced at this minimum biodiesel price is significantly lower (22265 litres) under the less optimistic scenario.

Only at a farm-level biodiesel price of R12.79/litre does the less optimistic solution combine the largest Low-Tech biodiesel plant (Plant2) with the smallest oil extrusion plant. At this price the identical quantity of biodiesel (86184 litres) is produced as in the minimum price (R10.55/litre) case under the optimistic assumptions. Moreover, the minimum biodiesel price required to draw in the High-Tech biodiesel plants into the optimum solution under the less optimistic assumptions is R13.10/litre. This is R2.10/litre higher than the optimistic scenario, to achieve the identical level of biodiesel production, using the same combination of plants. This less optimistic scenario, therefore, is even more heavily dependent on buying in soybeans (15485 tons).

Table 6: Less Optimistic Baseline Results under Various Farm-Level Biodiesel Prices, assuming Soybean Oil = R7.90/litre and Soybean Oilcake = R3300/ton

Investment Behaviour						
Biodiesel Price (R/litre)	6.55	8.55	10.55	11.47	12.79	13.10
	(Baseline)					
Oil Extrusion						
Plant 1	No	No	No	Yes (1)	Yes (1)	Yes (1)
Plant 2	No	No	No	No	No	Yes (7)
Sell Soybean Oil (litres)	0	0	0	0	0	0
Sell Soybean Oilcake (tons)	0	0	0	266	514	10796
Biodiesel						
Plant 1 (Low-Tech)	No	No	No	Yes (1)	No	No
Plant 2 (Low-Tech)	No	No	No	No	Yes (1)	No
Plant 3 (High-Tech)	No	No	No	No	No	No
Plant 4 (High-Tech)	No	No	No	No	No	No
Plant 5 (High-Tech)	No	No	No	No	No	Yes (1)
Sell Biodiesel (litres)	0	0	0	44528	86184	1809864
Sell Glycerine (tons)	0	0	0	88	171	3593
Buy Soybean (tons)	0	0	0	0	365	15485
Objective Function Value	467 113	467 113	467 113	467 203	528 532	559 324

6. Conclusion

Historically, alternative energy technologies, including biofuels, have been dependent on sustained governmental support in order to be competitive with fossil fuels in the marketplace. Accordingly, global biofuel production has risen substantially in recent years, driven primarily by government support in these industries. The stated motivations for biofuel initiatives are numerous and have varied over time. While a significant driver of the recent increases in biofuel production has been the rising real crude oil price, prolonged government intervention has undoubtedly been an essential feature of the development of the biofuel industries in many of the present global market leaders in biofuel production. Trends indicate that this will continue in the future. Biofuel development can be influenced by numerous national policies, in multiple sectors, at various stages in the supply chain – ultimately creating favourable market conditions for the production of biofuels. While a wide variety of policy tools are available for government intervention in biofuel markets, the cost effectiveness as well as the distributional implications of each will vary, creating both winners and losers among economic agents. Nevertheless, excise tax credits, renewable fuel standards and mandatory blends appear to be the norm.

Whilst numerous Asian and Latin American countries are becoming increasingly important biofuel producers, Africa's current contribution to global biofuel production levels can be regarded as being comparatively insignificant. However, with a relative abundance of underutilised land and labour, as well as favourable growing conditions, various African countries have been identified as having significant biofuel production potential. However, very little research on biofuels has been conducted from a SA standpoint. It has been suggested that batch biodiesel processors are most suitable in the African context. This article provided an economic evaluation of this proposition. The preliminary results presented indicate that considerable government intervention is necessary to establish and operate batch process biodiesel plants on commercial crop farms in the historically high soybean-producing areas of KZN. Importantly, these results, under both optimistic and less optimistic conversion ratio scenarios, support the study by Funke *et al*. (2009), who contend that the incentives and commitments proposed by the SA biofuels industrial strategy are insufficient to both establish and sustain a domestic biodiesel industry. On-going research intends to refine and explore possible alternative biodiesel policy measures and their respective impacts on potential crop farmer investment behaviour in these regions of KZN. The influence of (optimal) farm size on such decisions will also be analysed.

Bioethanol and biodiesel are currently the leading biofuel varieties produced worldwide. The most prominent contribution of these biofuels will likely be to augment the existing supply of fuels used in transportation sectors. However, under current production levels biofuels contribution to global energy demand is modest. Therefore, despite the fact that global biofuel production levels are expected to continue to increase in the future, they are unlikely to be a panacea and should be used in conjunction with other renewable energy technologies, as outlined by the Renewable Energy White Paper. There are, however, concerns that South Africa's commitment to this initiative is not binding. Nevertheless, continued technological advancements, infrastructure development and government interventions will certainly be central to the future developments of biofuel industries, both globally and locally.

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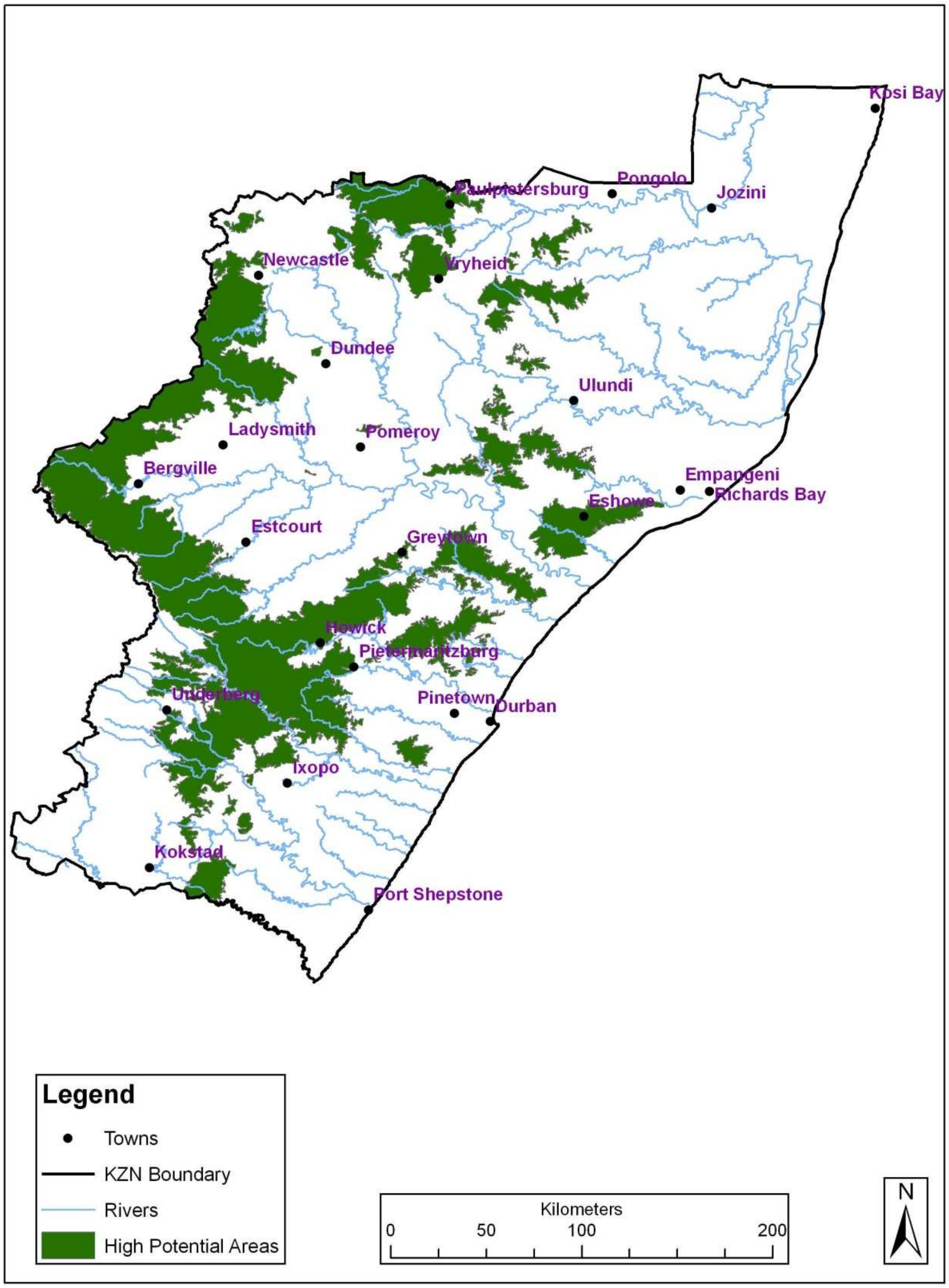
Appendix A: Regions in KwaZulu-Natal of Historically High Soybean-Production and Significant Cropping Potential for Future Expansion of Soybeans



(Source: KZNDAEARD, 2010)