Biodiesel production in New Zealand – opportunities and considerations

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Abstract
Biodiesel is frequently promoted as an alternative 'green' energy source that could lead to fuel security for the transport and farming industries. However, the growing of such crops has been criticised for taking valuable arable land out of food production and thus, in fact, reducing food security. To mitigate these effects, it has been proposed that marginal soils be used for biodiesel crop production.
In this New Zealand study a diverse range of oilseed species were evaluated for biodiesel production on both high quality arable soils and on marginal land. On the marginal soils grain yield and oil production were low and variable, with Camelina (*Camelina sativa*) and canola (*Brassica napus*) out-yielding all other species tested. On the higher quality arable soils much higher yields were achieved, with canola out performing all other species tested.

In New Zealand, dryland marginal soils are primarily used for intensive sheep meat production or where irrigation is available, may have been converted to dairying; therefore the notion that these soils are not used for food production is simplistic. Changing farming systems on these marginal soils to biodiesel production would lead to increased farm risk. Alternatively, producing biodiesel from high producing canola crops on quality arable soils would likely provide benefits such as improved crop rotations and regional fuel security.

Key words
Biofuel, fuel security, marginal soils, oilseed crops.

Introduction
In 2006 the New Zealand government passed legislation that required oil companies to meet a biofuels sales obligation which required 3.4% of total petrol and diesel sold be biofuel by 2012. To support this the Biodiesel Grants Scheme was established which allowed for grants of up to 42.5 cents per litre to eligible biodiesel producers. The purpose was two-fold: biodiesel would decrease greenhouse gas emission by 19-54% (Campbell and McCurdy 2008; Tate and Purchas 2008) and increase New Zealand's fuel security as oil production occurs in volatile regions of the world. Diesel use in New Zealand is 111 PJ (Rosevear 2008) which converts approximately to 3 billion litres. Agriculture, industry, transport and the retail sector accounts for 10.6, 12.2, 24.8 and 40% of diesel use respectively (Rosevear 2008). The level of biofuel production needed for the governments mandated percentage is approximately 100 million litres. It is estimated that recycled cooking oil could produce 3 to 5 million litres whilst tallow could produce 150 million litres although there are higher value markets available for tallow (Hale et al. 2006). However, the legislation on mandated levels and the subsidy of biofuels has since been repealed and lower oil prices have reduced fuel security concerns.

In temperate environments, canola (*Brassica napus* L.) is the main crop source for biodiesel. Increasing the area of crops for biofuel production has been criticised for impacting on food security because land that was once producing food has been switched to fuel production resulting in increased food prices (Timilsina and Shrestha 2011). There is therefore an interest in using marginal land for biodiesel crops to reduce the direct competition. The programme described in this paper aimed to identify for NZ new oil bearing plants with the potential for use as biodiesel feedstock. The crops should be produced sustainably on marginal land, should not be major arable food crops and should not require high fossil-fuel based inputs. Approximately, 1.4 Mha of land in New Zealand is classified as highly suitable for arable farming (LUC 1 and 2), about 2.4 Mha is considered as arable but with moderate limitations, whilst 2.8 Mha arable land has severe limitations (Our Environment 2014). Interestingly, harvest data of all the main seed crops reveals approximately 200, 000 ha sown each year (Agricultural Census tables 2012). The area is increased by a further 400, 000 ha when annual forage brassicas, cereal forage crops and maize silage are included (Agricultural Census tables 2012). In comparison, exotic grassland covers 10.5 Mha including flat cultivatable land and hill country (Our Environment 2014). Marginal land can include stony soils with low water holding capacity, low fertility soils and pumice soils. Other oilseed species that were included in the programme were, camelina (Camelina sativa L. (CS)), brown mustard (Brassica juncea L. (BM)), meadowfoam (Limnanthes alba Hartw. (MF)) and pennycress (Thlaspi arvense L. (PC)).

Method

Field experiments 2009 and 2010

In 2009 and 2010 five oilseed species at three different sites were sown in autumn and spring. Only autumn sown treatments are presented here. Further details are described by McKenzie *et al*. (2011). Locations included Ashley Dene - 7km from Lincoln, with a very stony silt loam soil. Oxford, in the foothills of the southern Alps, a very wet and low phosphorus site; and Taupo in the North Island with a light pumice soil. Nitrogen was applied at each site at 50 and 150 kg/ha although only the high nitrogen treatment is reported here. In 2009 sowing occurred at Ashley Dene on 5 May, at Taupo on 11 June and sowing was delayed at Oxford due to a wet autumn and occurred on 27 August. Autumn sowings at Ashley Dene of canola and BM were re-sown on 25 June due to bird damage. In 2010 sowing dates at Ashley Dene was 18 March although autumn sown CS was abandoned due to plant death. Only spring sowing was conducted at Oxford and Taupo in 2010 and is not included in this data. Biomass and development was measured throughout the season but only grain yield is reported here.

Field experiment 2010

An experiment with three oilseed species over four sowing dates was conducted on a deep silt loam soil at Lincoln University in 2010. Only the March sowing date is reported here. Further details are described by (Fasi et al. 2012). The experiment was irrigated at 50% plant available water to prevent water stress. Biomass and development was measured throughout the season but only grain yield is reported here.

Commercial field sites 2012

Field sites were established throughout the main cropping zones in New Zealand with the primary purpose of providing validation data for APSIM (Agricultural Production Systems sIMulator) modelling, but this work is not reported here. Location of the sites included; Hilderthorpe, Waimate, Makikihi, Fairlie (x2), Cave, Temuka, Kirwee, Burnham, Fielding (x2) and Sanson. All locations were on cropping farms with quality arable soils and/or irrigation available. All agronomic management was conducted by the co-operating farmer with four replications of measurements taken from a fixed area within the crops. Biomass and development were measured throughout the season but only grain yield is reported here.

Results

Seed yield was highly variable across sites and seasons (Table 1). When sown on a low water holding capacity soil at Ashley Dene in 2009, May sown MF produced 1551 kg/ha and was the most productive species. The canola and BM was re-sown which resulted in reduced yields less than 900 kg/ha. Seed yields at Oxford and Taupo were greater than for Ashley Dene primarily because soil water was less limiting. At Oxford, canola achieved the highest seed yield. Sowing in June at Taupo resulted in canola and BM yielding more than CS while Meadowfoam performed very poorly. Pennycress failed to establish properly at most sites due to disease and weeds. It was identified that canola and BM were the most promising species for further development on marginal soil. Camelina was also included as it had performed well in spring sowings (data not shown).

Table 1. Seed yield of five species at four sites in New Zealand

Year	2009			2010	
Site	Ashley Dene	Oxford	Taupo	Ashley Dene	Lincoln
Sow date	May[a]	August	June	March	March
Canola	823	2448	2304	1490	2939
BM	201	1577	2078	307	773
CS	601	1105	1397	-	664
MF	1551	401	476	ns	ns
PC	-	-	-	ns	ns
Signif	< 0.01	< 0.01	< 0.001	NS	< 0.01
LSD	631	336	787		471

[a] OSR and BM were resown on 25 June. NS – not significant. ns – not sown.

In 2010 at Ashley Dene, the autumn sown CS died during winter while canola had increased yield compared to the previous season but was variable. Canola produced the greatest yield for March sowing at Lincoln University in 2010. Not only were seed yields different, but oil yield percentage was different between crops; canola averaged 42% compared with BM and CS at 30 and 33% respectively. Therefore canola not only out yielded the other species but also produced a greater concentration of oil.

Seed yield from commercial canola crops across New Zealand were compared and ranged from 3177 to 5936 kg/ha, at an average of 4500 kg/ha. Crops achieved high harvest indices with an average of 35% and an average thousand seed weight of 4.5g.

Estimating how much land would be required to meet the biodiesel requirements was extrapolated from oilseed yields (Figure 1). If the total mandated requirement was to be met through oilseed production on high quality arable land this would require approximately 60,000 ha with an average yield of 4500 kg/ha. Reducing the biodiesel requirement (but still with a seed yield of 4500 kg/ha) to 50 and 25 million litres would reduce the required land area to 30,000 and 15,000 ha respectively. Moving crops to marginal soils in which maximum yield was 1500 kg/ha would require three times this land area.

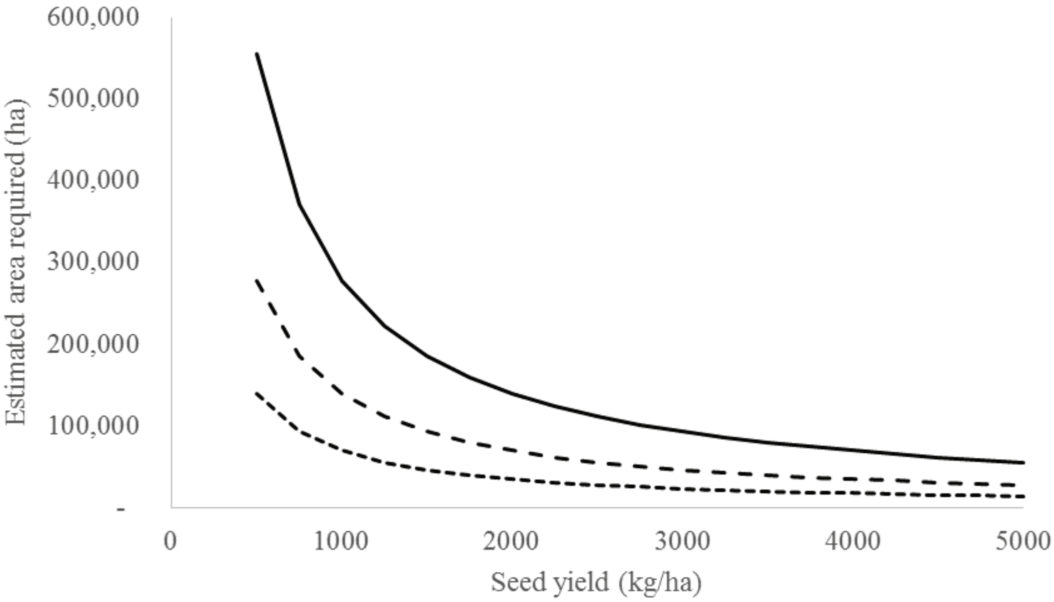

Figure 1. Estimated area required for three levels of biodiesel production (100 million litres solid line, 50 million litres dashed line and 25 million litres dotted line) for a range of seed yields.

Discussion

Under a range of soil conditions canola was as productive or more productive than the other species considered. These results should not be surprising because of the large investment into breeding improved cultivars of canola over many decades. In fact, there is likely to be a number of canola cultivars bred for short-season conditions that were not tested here due to their lack of availability in New Zealand. *Camelina sativa* could be a useful species for New Zealand environments but it has not received the same concerted breeding effort. What should be noted is the yield potential differences between marginal soils and better arable soils. For soils with low water holding capacity seed yield appeared to be limited to 1500 kg/ha and to be highly variable. Canola sown in 2010 on better soils achieved 2900 kg/ha whereas farmers across 12 sites achieved an average of 4500 kg/ha with a maximum yield of 5936 kg/ha. Therefore it is questionable whether oilseed crops for biodiesel production be sown on marginal land. If marginal soils could average 1500 kg/ha, the area required to reach the New Zealand's governments previously mandated biodiesel quota would be 185,000 ha. Alternatively, if the canola was grown on high quality arable land with an average yield of 4500 kg/ha then 60,000 ha would be required. However, it should be noted that currently only 200,000 ha per annum is currently used for growing seed crops. Creating a biodiesel industry derived from oilseed crops would require a significant change in land use right across New Zealand. The land area required to reach the previous government's quota is very large, especially if crops from marginal soils were to be included, and the biodiesel industry would have to compete with other industries such as dairy, processing crops and high value seed crops for land and resources. It is unlikely that grain for fuel could compete with these high value industries. If canola was used in the rotation on high quality soils every 5-10 years this would result in 20-40,000 ha being sown each year. This area of production would not satisfy a national demand for fuel but could supply a regional based industry.

Furthermore, the consideration to use marginal land instead of high quality arable land was due to concerns about encroaching on land that is required for food production. In New Zealand, marginal land is used for food production, primarily for sheep meat production. If the land has irrigation it could also be used for dairying. With regard to global food security, it is the increase in the animal protein requirements of the rising middle classes of developing countries that is likely to put the greatest pressure on production and also on ecological systems. Using marginal soil for cropping would directly impact on the production of grass-fed animal protein which tends to have a low environmental impact. Changing land use on marginal soils from pasture to cropping land is likely to increase risks to farmers without any improvements in financial returns. Grazing of pastures in autumn and spring is highly reliable compared to the growing of an annual grain crop, because such crops must reach full maturity before harvest, leaving them vulnerable to the weather. As shown in the Results section, there can be large variations in seed yield within and between seasons.

It is unlikely that the production of biodiesel will become a national industry due to the land requirement and competing industries. However, that does not mean that a regionally-based biofuels industry could not be successful. Arable farmers are able to produce high yielding canola crops and would require very small areas of land to supply their own needs. An arable farm may use 100 litres of diesel per hectare. Therefore, to be self-sufficient, a canola crop with a yield of 4500 kg/ha would only require approximately 6 ha for every 100 ha of crops sown. This would not greatly change the diesel use profile in New Zealand, but it could boost regional communities, secure their fuel supply and stabilise the price of fuel.

Conclusion

On marginal land, canola is as productive and often more productive than other alternative oilseed crops, but yields on marginal land are low and variable compared to those from high quality arable land. Producing biodiesel on marginal soils affects food production because in New Zealand these soils are used for the production of sheep meat and dairy products. To produce sufficient diesel to reach original government mandated quotas would require large areas of land compared to the areas that are currently used for cultivation. Producing biodiesel from canola on high quality arable soils in support of regional industries could reduce farmers' reliance on world oil production and increase regional economic activity.

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