Potential biodiesel crops for marginal land in Australia

Daniel K.Y. Tan[1], Inakwu O.A. Odeh[1], Tihomir Ancev[1]

Faculty of Agriculture and Environment, University of Sydney, NSW, 2006
Australia. **www.usyd.edu.au** Emaildaniel.tan@sydney.edu.au

Abstract

Biodiesel is being promoted as a renewable replacement for diesel derived from fossil fuels. This is mainly because biodiesel has favourable properties such as low sulfur content, in addition to its potential environmental benefits. Currently, most biodiesel is produced from food crops growing on arable land, such as soybean in USA and rapeseed in Europe. Due to food security concerns, some developing countries, e.g. India and Pakistan, are promoting tree crops, such as jatropha (*Jatropha curcas*) and pongamia (*Millettia pinnata*) to be grown on marginal land. In Australia, cultivation of Jatropha is discouraged due to its similarities to the bellyache bush (*Jatropha gossypiifolia*), a significant pasture weed in northern Queensland. As such, a number of alternative crops, including moringa (*Moringa oleifera*), pongamia and Indian mustard (*Brassica juncea*), are currently being considered for cultivation on marginal agricultural land in Australia. This study shows that while the perennial tropical tree crops moringa and pongamia are more suitable for northern Australia, Indian mustard is adapted to both subtropical and temperate areas. Modelling of future climate change projections suggests that the marginal agricultural land may shift towards the coast, encroaching into areas currently considered arable land, and reducing the area suitable for future biodiesel feedstock production. Under these scenarios, tree crops may offer added opportunities for agroforestry in northern Australia, providing shade for cattle as well as supplying biodiesel for regional towns, cattle stations and mines. Additionally, Indian mustard may provide potential biofumigation and crop rotation benefits to other annual crops in the temperate region of eastern Australia.

Keywords

Bioenergy, biomass, biodiesel, biofuel, crop agronomy, marginal land

Introduction

Currently Australia imports 30% of its oil products and this is projected to increase to 76% by 2030; and only 0.5% of Australia's transport fuel is supplied from biomass (Geoscience and ABARE 2010). If Australian oil production continues to decline, and oil prices increase, the net oil imports could cost Australia almost A$70 billion p.a. in real terms by 2029-2030 (CSIRO 2011). In Australia, bioethanol and biodiesel are produced from biomass as renewable alternatives to gasoline and diesel, respectively. At present, the main biodiesel feedstocks are sourced from tallow, used cooking oil and canola oilseeds; the shortage of suitable quality feedstock is a key constraint for the biodiesel industry. The total diesel consumption in 2009 was 19 GL with 48% of this imported (Geoscience and ABARE 2010). Despite the development of microalgae as a feedstock for biodiesel production, there are problems scaling up from laboratories to commercial production (Campbell*et al.* 2011; Razif *et al.* 2011). In the USA and Europe, biodiesel is produced from soybean and rapeseed, respectively. However, to avoid the "food versus fuel" debate in Australia, several authors have proposed that bioenergy should potentially be sourced from crops grown in marginal agricultural land (Holtum *et al.* 2011;Odeh *et al.* 2011; Yan *et al.* 2011; Farine *et al.* 2012). This paper discusses some feedstocks suitable for production on marginal land for biodiesel production in Australia.

Jatropha

Jatropha (*Jatropha curcas*) is a tropical perennial tree belonging to the family Euphorbiaceae. It is a native of tropical America and is now naturalised in many parts of the tropics and sub-tropics in Africa and Asia (Koh and Ghazi 2011). In Australia, jatropha has been banned by the Agriculture Protection Board of Western Australia (WA) due to its genetic and ecological similarities to bellyache bus (*Jatropha gossypiifolia*), a significant weed in northern Queensland (Bebawi *et al.* 2011). The recent failure of jatropha in India and other developing countries due to lack of bioenergy policy and R&D, emphasises the need for investment in R&D before embarking on large-scale investments (Kant and Wu 2011).

Moring

Moringa (*Moringa oleifera*) is a subtropical perennial tree belonging to the family Moringaceae. It is a native of India, Africa, Arabia, Southeast Asia and South America (Umer *et al.* 2008). Moringa has the potential to be grown in the Albany, Carnarvon, Esperance and Geraldton regions and the tropical north of Western Australia and has been planted by aboriginal groups as well as in experimental stations in Carnarvon and Albany (Biswas and John 2009). A lifecycle assessment has shown that greenhouse gas (GHG) emissions during the production of 1,000 L of biodiesel from moringa oilseeds was 33% lower under dryland conditions (1,171 kg CO_2-e) compared with under irrigation (1,543 kg CO_2-e) (Biswas and John 2009).

Pongamia

Pongamia (*Millettia pinnata*, formerly known as *Pongamia pinnata*) is a tree legume that is drawing attention as a possible biofuel feedstock in Australia (Scott *et al.* 2008). It belongs to the family Fabaceae, in the subfamily Papilionoideae, and is a native of India, Myanmar, Malaysia, Indonesia and northern Australia. There are reports of pongamia being used by aboriginal people of northern Australia as a source of timber and fish poison (Scott *et al.* 2008). Pongamia is able to form functional spherical nodules with a broad range of rhizobia belonging to the Bradyrhizobium tribe. The seeds contain about 40% extractable oil predominantly in the form of triglycerides. The oil is rich in C18:1 fatty acid (oleic acid) and has relatively low amounts of palmitic and stearic acid, making it useful for the manufacture of biodiesel (Kazakoff *et al.* 2010). The potential yield in Australia has been estimated at approximately 20,000 seeds/tree/year or 12.6 tonnes of seed per ha based on 350 trees/ha from 10 year old trees. Hence, an estimated area of 7,000 km^2 would need to be harvested to satisfy the existing 19 GL annual diesel consumption of Australia (Scott *et al.* 2008).

Pongamia has been used as a biofuel in India for some time now, and is well-suited to marginal land as it is regarded as both a saline and drought tolerant species. In pot experiments saplings grew well at saline levels up to 20 dS/m and nodulation of pongamia was not adversely affected until irrigated with water of 10 dS/m (Kazakoff *et al.* 2010). An average annual minimum rainfall of between 500-800 mm is required for persistence of pongamia, and established trees (6-10 years) survived 4 months without rain in Brisbane during the 2007-8 drought (Murphy *et al.* 2012). Pongamia can survive maximum temperatures exceeding 45°C. Pongamia cuttings and saplings (60 cm in height) survived 65 °C in a greenhouse when the temperature control unit failed during the 2011 Brisbane flood, though ample water was available (Murphy *et al.* 2012). Pongamia can survive and recover from frost events but is not considered 'frost tolerant'(Murphy *et al.* 2012). In Australia, pongamia is cool- and possibly drought-deciduous, undergoing a winter dormancy period. Plants do not grow new leaves in spring until minimum temperatures are consistently greater than 15 °C (Murphy *et al.* 2012). Mature plants appear to survive moderate water-logging, though some mortality may occur. Pongamia seed yield is severely affected by heavy rain periods during flowering time. During the heavy rain in Nov/Dec 2010 in southeast Queensland, flowers collapsed either because of rain or absence of insect pollination (Murphy *et al.*2012). Bees are the main agents for pongamia pollination (Raju and Rao 2006).

In India, the de-oiled cake of pongamia is used as a feed supplement for cattle, sheep and poultry. De-oiled cake is the leftover component of seed following solvent extraction and contains up to 30% protein (Scott *et al.*2008). As a native tree, pongamia plantations may satisfy the rules of the Carbon Farming Initiative (CFI) due to positive carbon sequestration activity and growers may get credit for voluntary participation in the CFI scheme (Murphy *et al.* 2012). Opportunities exist for a sustainable pongamia agroforestry program to supply biodiesel to regional towns, cattle stations and mines in northern Australia with substantial infrastructure investment in processing plants (Odeh *et al.* 2011). Research needs to be undertaken to determine how these biodiesel industries might best be integrated with the existing livestock industries.

A breeding program for elite varieties from existing superior germplasm is now being undertaken by the ARC Centre of Excellence for Integrative Legume Research at the University of Queensland. Plantations have now been established in southern Queensland (Gatton, Yandina, Eudlo and Caboolture), Roma in south-central Queensland and Kununurra in northern Western Australia. Modelling using the CSIRO Mk 3.0 A1B emission scenario suggests that the total marginal area (300 – 600 mm annual rainfall zone) suitable for growing pongamia between 2040 and 2070 is substantially different from the suitable marginal area under the current climate, indicating that long-term investments in this crop may not be viable in all regions in Australia (Figure. 1a) (Odeh and Tan 2007; Odeh *et al.* 2011).

Indian mustard

Indian mustard (*Brassica juncea*) is an annual oilseed crop belonging to the Brassicaceae family. Its centre of origin is believed to be in the Central Asia Himalayas, with migration to the secondary centres in India, China and Russia (Odeh and Tan 2007). It is very drought-tolerant (annual rainfall 300-400 mm) and many varieties can express greater osmotic adjustment than canola (Niknam *et al.* 2003). Indian mustard was up to 50% more productive than canola under very dry conditions, but not under normal rainfall conditions in northwest NSW (Robertson *et al.* 2004). An Indian mustard breeding program for biodiesel production was commenced in 2006 at the University of Sydney I.A. Watson Plant Breeding Institute at Narrabri with funding from ARC Linkage and RIRDC. Indian mustard is now part of the four year rotation at the Narrabri research station. Germplasm was obtained from the Victorian Department of Primary Industries and the breeding programs at the University of Faisalabad in Pakistan. The first lines were developed from outcrosses using pollen bulks among the Victorian based materials. New lines were tested in regional multi-locational field experiments in 2009, 2010 and 2011, and several candidate lines for release have been identified. Six hundred advanced lines based on Pakistani/Australian crosses have been tested in 2011. Double haploids of Pakistani/Australian crosses have been made using microspore culture. The plantlets were treated with colchicine to promote chromosome doubling. The first double haploid derivatives of these materials were increased in 2010 for testing in 2011. At the research station, there are two BioMaster 150 L biodiesel batch processing plants to provide biodiesel self-sufficiency. Oil is extracted from grain and converted to biodiesel. Feeding trials for livestock are also being carried out for the mustard presscake as a protein source for growing ruminant animals (McKinnon and Walker 2009). The key agronomic advantage of Indian mustard (and canola) is the biofumigation properties as a rotation crop with cereals, that reduce soil-borne diseases such as crown rot and nematodes which can severely limit yield in winter cereals (Smith *et al.* 2004). Modelling using CSIRO Mk 3.0 A1B emission scenario suggests that the total marginal area (300 – 600 mm annual rainfall zone) suitable for growing Indian mustard will have completely encroached into the current grain belt of northern Queensland and northern NSW by 2050 and 2070 (Figure. 1b) (Rogers *et al.* 2010; Odeh *et al.* 2011).

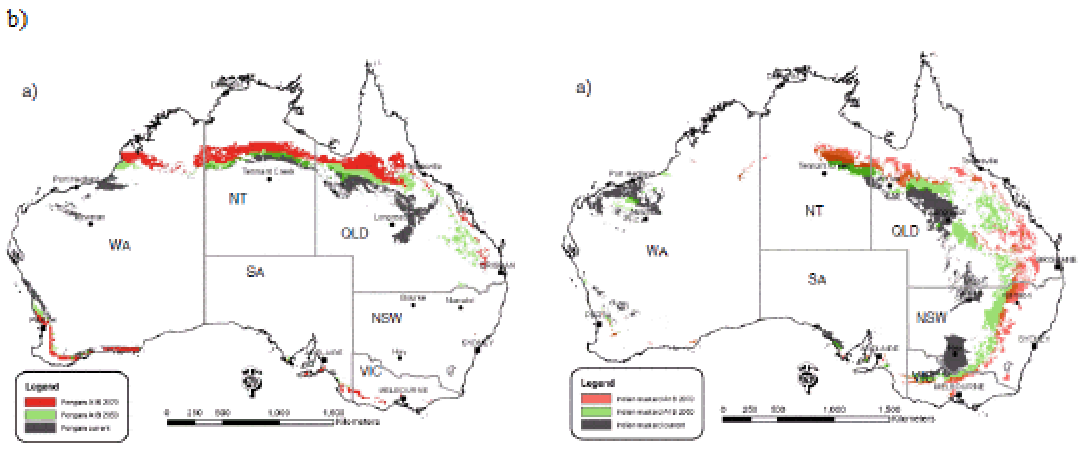

Figure. 1. The spatial distribution of projected suitable areas for (a) pongamia and (b) Indian mustard due to A1B climate projections in 2050 and 2070 compared with the current suitable marginal areas (Odeh *et al.* 2011).

Conclusions

Future biodiesel production should be sourced from crop feedstocks such as moringa, pongamia and Indian mustard, that can be grown on marginal land. This will ensure establishment of a sustainable biodiesel industry that will not compete for land and other resources with the rest of the agricultural sector that produces food and fibre. In addition, sustainable biodiesel production will rely significantly on the capacity to run economically viable and profitable operations that will be resilient to fluctuations in fossil and non-fossil fuel prices, and government policies in relation to renewable energy and carbon emission reductions.

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