Expanding Biofuel Production in Australia: Opportunities Beyond the Horizon

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The search for alternative energy in Australia (and indeed the rest of the world) has emerged as one of the greatest challenges of the 21st century. While it has generally been predicted that the national target of 350 million litres biofuel production by 2010 will easily be met, expansion above this target has some economic and environmental implications, among which is competition with food and cash crops grown on existing arable lands. This necessitates opportunities outside current arable lands, especially in marginal agricultural regions, which potentially are amenable to the production of some exotic biofuel crops, namely: pongam, physic nut and Indian mustard. A preliminary assessment of the marginal regions in mainland Australia indicates that 20–30 million hectares are potentially suitable for the production of each of these exotic crops. It is envisaged that production up to a small fraction of the estimated area will provide enough feedstocks to supply up to 50% of national diesel needs.

With the recent rise in fossil fuel prices and growing threat of global warming, biofuels are increasingly seen as alternative energy sources and solutions to both high energy costs and concerns about greenhouse gases. Recent developments in Asia, South America and most of the industrialised world have witnessed enthusiastic pursuits to develop the bioenergy sectors to meet the need and increasing demand for alternative and sustainable energy sources.

In Australia, efforts are underway to create a sustainable biofuel industry with the targeted production of 350 million litres (ML) by 2010 (CSIRO et al. 2003). While this level of production accounts for approximately 1.1% of the national fuel supply, a recent report by the Australian Government's Biofuels Taskforce (2005) claimed that the pre-existing government policy settings were sufficient to meet the target of 350 ML by 2010 if the mainstream markets for biofuels were favourable. According to a report by the Australian Bureau of Agricultural and Resource Economics (ABARE), 2005–06 production stands at only 57 ML, less than one-fifth of the 2010 target (ABARE 2007a). What is hindering the uptake and expansion of biofuel production in Australia?

The report of the Biofuels Taskforce (2005) enumerated a number of economic and commercial reasons for the slow progress of biofuel uptake and, hence, expansion in Australia, including:

1. A highly competitive market faced by oil companies without long-term economic incentives to adopt alternative supply options such as biofuel sources.
2. Unjustifiable lack of consumer demand for ethanol blends caused mainly by poor consumer confidence.
3. Little commercial incentive for the oil sector to promote ethanol and biodiesel blends as the mainstream fuels due to the lack of consumer demand.

4. Doubtful viability of the biofuel industry beyond 2011 because domestic biofuel producers will not be protected from international competition through government subsidies.

In contrast to the Taskforce's findings, a more recent independent study into the development of alternative fuels in Australia found that the nation's capacity to produce ethanol and biodiesel should easily reach the Federal Government's target of 350 ML by 2010. The study report, *Biofuels in Australia – A Growing Sector* (Bethune & Cochran 2006), found that continuous expansion and uptake of biofuels by consumers will be determined by key elements including cost of production, consumer confidence and government subsidies. In a bold forecast, Bethune and Cochran (2006) envisaged that Australia's biofuel production capacity is likely to exceed 640 ML a year by the end of 2007 and expand to nearly 2,400 ML (equivalent to 7.5% of the national petrol and diesel consumption) by 2010 if current plans are implemented. A major challenge is the limited capacity of domestic feedstock supply. Will grain and sugarcane production be able to match the feedstock demand required for such expansion?

While Bethune and Cochran (2006) have painted an optimistic picture of future biofuel production in Australia, there are also other concerns, among which are that the expansion in biofuel production may consequently lead to:

- arable land and water being increasingly diverted for biofuel production
- increased competition for feedstocks by multiple industries, including beverages and livestock feedlots
- higher and less stable food prices
- exacerbated hunger in developing countries
- increased use of pesticides and herbicides, which will add to environmental pollution and degradation.

These concerns, especially the issue of competition for arable land, necessitate the search for other options for the supply of biofuel feedstocks, including possible expansion outside the arable regions of Australia.

Based on the forecast by Bethune and Cochran (2006), the increased biofuel production would lead to rising costs and limited supplies of major feedstocks, such as sorghum to produce ethanol and tallow to produce biodiesel. For the forecasted production of over 2,000 ML a year to be realised, an unpalatable and perhaps unsustainable option is for Australia to utilise some of its export grain supplies. This will not augur well for Australia's economic security. Alternative sources of feedstocks are therefore required.

The focus of this paper is how Australia can increase the supply of feedstocks through expansion of biofuel crop production beyond current arable lands. The paper examines alternative sources of feedstock for biofuel production through exotic crops suitable for some of the harshest conditions in marginal regions of Australia, and outlines the agronomic and environmental conditions for these exotic crops. How these conditions provide good prospects for expanding biofuel crop production into the marginal and/or degraded regions of Australia will also be explored.

Limitations of the Current Biofuel Feedstocks in Australia

The capacity for biofuels to contribute to national transport fuel demand as contained in the current plan (CSIRO et al. 2003) is quite limited. In 2005–06, Australia produced and consumed 57 ML of biofuels, consisting of 41 ML fuel ethanol and 16 ML biodiesel, which is approximately 0.1% of national fuel consumption (Love & Cuevas-Cubria 2007). If, by 2010, the Australian Government's target of at least 350 ML were to be met, this will contribute to only approximately 1.1% to the total transport fuel supply. To expand to more than 350 ML using the current feedstocks requires some bold steps that will affect the agricultural sector. To put it in perspective, diverting the entire Australian wheat and sugar crops to biofuel production has been calculated to satisfy less than 20% of Australian current transport fuel use (Fleay 2006). In order to meet the forecasted production of over 2,000 ML a year by 2010 (Bethune & Cochran 2006), other feedstocks need to be explored beyond the current sources of feedstocks that are in direct competition with traditional export and domestic agricultural produce.

Ethanol production

Sorghum, wheat and, to a lesser extent, sugarcane, are currently the main sources of feedstocks for ethanol production in Australia. The supply regions are located in the grain belt, while molasses derived from sugarcane is used by producers located in coastal north-east Australia. Since feedstock costs represent 60–70% of operating costs, fuel ethanol producers face concerns over the rising cost of feedstock and securing a regular supply of feedstock. There is limited scope for increase in land area planted to sugarcane because of constraints imposed by government regulations and geographic suitability. It is well known that sugar is a high water-use crop that requires up to 1,000 litres of water to produce 1 kilogram (kg) of sugar, or 1ML of water to produce 12.5 tonnes of commercial cane. Additionally, ethanol production from this feedstock would need to compete with the other domestic sugar consumption and the price of ethanol would have to be at export parity price (Rabobank 2006).

If all projected grain-based ethanol producers commence operation, they would require about 2.5 million tonnes (Mt) of grain a year by 2011–12 (Love & Cuevas-Cubria 2007). It is unlikely that this could be supplied by sorghum (averaging 2 Mt a year), traditionally the lowest priced coarse grains where an average of 1.7 Mt a year is consumed by the domestic feedlot livestock industry. More wheat (averaging 24 Mt a year) than sorghum is produced, but domestic consumption averages 5.3 Mt a year with the balance exported. During drought years such as 2006–07, production of wheat and sorghum could be more than halved to about 9.8 and 1.0 Mt a year, respectively (Table 1).

Hence, ethanol producers requiring at least 2.5 Mt of grain would represent a potential increase in total domestic sorghum and wheat use of the order of 35% (Love & Cuevas-Cubria 2007). This would put undesirable pressure on Australia's export earnings.

Perhaps the next generation of technology will enable the production of ethanol from cellulosic feedstocks (eg crop residues, grass and trees), but this technology has yet to be proven commercially viable at present (Australian Government Biofuels Taskforce 2005).

Biodiesel production

Apart from fats and oils (including used cooking oil and tallow), canola seeds are used as feedstock by biodiesel producers (Love & Cuevas-Cubria 2007). If all projected biodiesel facilities commence operation, the potential total feedstock would exceed 0.8 Mt. Industry estimates put the annual availability of used cooking oil at 0.05 Mt, while tallow averages 0.5 Mt a year – of which around 0.4 Mt is exported. Hence, over 0.3 Mt a year of canola feedstock would be required. The annual production of canola averages 1.4 Mt – of which 0.9 Mt is exported and the rest is utilised domestically (Table 1). In a drought year such as 2006–07, total production could be reduced further to 0.5 Mt a year. Accordingly, unless significant technological advancement can be achieved in either biofuel production or crop yields, increased demand for feedstocks will compete with human food consumption and feed demand from livestock production. This increased demand will place significant upward pressure on crop prices (ABARE 2007a).

Table 1: Production of potential biofuel feedstocks in Australia.

Feedstocks	2004–05		2005–06		2006–07	
	Mt	'000 ha	Mt	'000 ha	Mt	'000 ha
Wheat	21.9	13,766	25.1	12,980	9.8	11,138
Sorghum	2.0	803	2.0	889	1.0	427
Sugarcane	37.8	–	38.2	–	36.0	–
Canola seed	1.5	1,351	1.4	962	0.5	944

Source: ABARE 2007a; ABARE 2007b; Love & Cuevas-Cubria 2007

Alternative Sources of Feedstocks: Exploring Some Exotic Biofuel Crops

The potential exotic biofuel crops that are good candidates for marginal growing regions of Australia are pongam, physic nut and Indian mustard. These crops are currently being used as feedstocks for biodiesel production in India. This section examines the minimal agronomic and climatic conditions for their production and provides an exploratory assessment of the marginal regions of Australia that meet these conditions.

The marginal agricultural regions of mainland Australia are illustrated in Figure 1. The criteria used to delineate these regions include a climatic and plant productivity index, as derived by Australian Greenhouse Office (Kesteven et al. 2004). These marginal regions are outside the grain belt in southern Australia and tropical rainforests in northern Australia. The basic agronomic and climatic requirements of these crops are outlined below:

Pongam

Pongam (*Pongamia pinnata*) is a tropical perennial tree belonging to the family Fabaceae. It is a native of India, Bangladesh, Myanmar and Thailand. Interestingly, it is naturalised in the humid tropical lowlands around the world, including north-eastern Australia (Food and Agriculture Organization 2001).

Basic agronomic and climatic requirements:

1. Mature trees can withstand light frosts (1°C) and temperatures up to 50°C (Ram & Pandey 1987; Sah et al. 1988). Reported growth temperature range of 10–50°C, with an optimum of 16–38°C.

2. Pongam is drought-resistant and well-adapted to adverse rainfall conditions. It is suited to annual rainfall range of 400–2,500 millimetres (mm) with the optimum between 500–2,000 mm (Food and Agriculture Organization 2001).

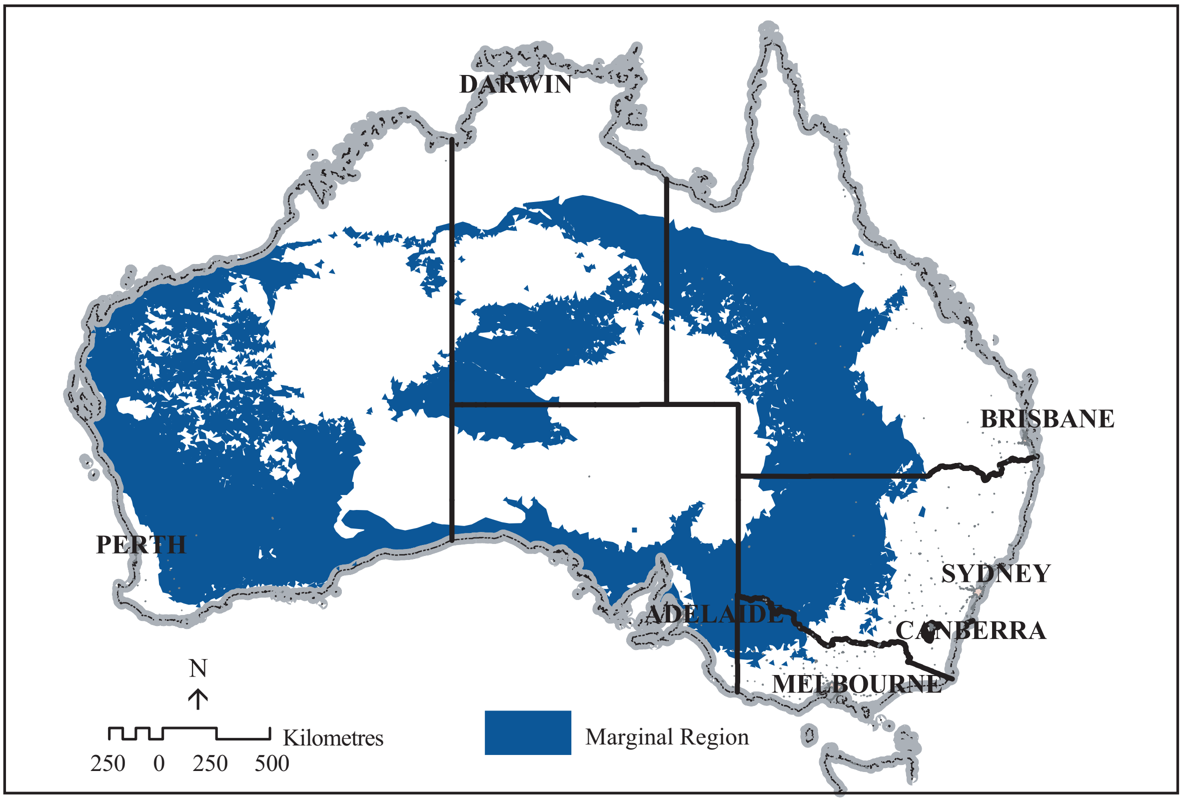

Figure 1: The marginal agricultural regions of mainland Australia.

3. Pongam can grow on most sand, stone or clay-based soil types including vertosols. However, it does not grow well on dry sands and is highly salt-tolerant (Daniel 1997; Singh & Yadav 1999; Chaudhry et al. 2002). Pongam does not have a high fertiliser requirement because, as a legume, it can fix nitrogen; it can also form associations with arbuscular mycorrhizal fungi (Chaukiyal et al. 2000; Pratiksha & Jamaluddin 2005).

4. Fruit yield is reported to vary from 9–90 kg per tree depending on the age of the trees. Mature seeds consist of 95% kernel which could contain up to 30% oil (biodiesel). Oil extraction is reported to be about 24–27% if mechanical expellers are used for the recovery of oil from the kernels.

Physic nut

Physic nut (*Jatropha curcas*) is a tropical perennial tree belonging to the family Euphorbiaceae. It is a native of tropical America, but now thrives in many parts of the tropics and sub-tropics in Africa and Asia (Openshaw 2000). Physic nut has been banned by the Agriculture Protection Board of Western Australia (WA) due to its genetic and ecological similarities to the bellyache bush (*Jatropha gossypiifolia*), a significant pasture weed in northern Queensland (Bebawi et al. 2005; DPAFWA 2006). However, the availability of non-toxic physic nut varieties from Mexico may offer potential for this tree crop in marginal areas of northern Australia.

Basic agronomic and climatic requirements:

1. Physic nut can grow in regions of low rainfall (200 mm per year minimum; 900–1,500 mm being optimal) and is drought-tolerant (Openshaw 2000).

2. The perennial tree is frost sensitive but salt tolerant and can grow under various soil conditions (including clay vertosols) and in rock crevices (Mishra et al. 2002; Lal et al. 2004; Dagar et al. 2006).

3. As physic nut is not a nitrogen-fixing species, fertilisers will have to be applied to maintain productivity. A deficient soil nutrient level may lead to increased failure of seed development (Openshaw 2000). If phosphorus is limiting, arbuscular mycorrhizal fungi may be found on the root system assisting with phosphorus and zinc uptake (Alok & Reena 2006).

4. Up to 31–37 % of oil (biodiesel) can be extracted from physic nut seeds. One major benefit is that the extracted oil can be used as biodiesel for any diesel engine, without engine modification.

5. However, as stated earlier, it is a declared weed in WA.

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 secondary centres in India, China and Russia (Idaho University 2007).

Basic agronomic and climatic requirements:

1. Research has revealed that Indian mustard is generally more easily adapted than canola (*Brassica napus*) to stressful environments associated with low rainfall, high temperature and late sowing (Gunasekera et al. 2006). It can be grown as a summer and winter annual crop.

2. Indian mustard is moderately frost-tolerant (up to -3°C) and can tolerate moderately high temperatures – up to 45°C (Dhawan et al. 1983; Rao et al. 1992).

3. It is very drought-tolerant (annual rainfall 300–400 mm) and many varieties can express greater osmotic adjustment than canola (Niknam et al. 2003).

4. Some preliminary investigations in north-west New South Wales (NSW) indicate that Indian mustard was up to 50% more productive than canola under very dry conditions, but not under normal rainfall conditions (Holland et al. 2003; Robertson et al. 2004).

5. Other studies in India suggest seed yields of 1–2 tonnes per hectare (t per ha), with an oil (biodiesel) content of 30–38%. A study carried out in California by Knowles et al. (1981) reported seed yields of 1.7–2.5 t per ha for some varieties.

Marginal Regions of Australia Potentially Suitable for Biofuel Crop Production

Based on the requirements for the production of the three biofuel crops listed in Table 2, an exploratory assessment of the marginal regions of Australia was conducted to determine suitable areas for growth and production. The assessment was based on combinations of climatic data sourced from the Australian Bureau of Meteorology; soil data from the Commonwealth Scientific and Industrial Research Organisation (CSIRO) Land and Water Division; and plant productivity index devised at the Australian Greenhouse Office by Kesteven et al. (2004). Some of the results of the assessment are presented in Table 3.

The results in Table 3 indicate 20–30 million ha (Mha) of suitable marginal areas for each crop. In summary:

- Pongam: up to 20 Mha of the marginal regions in mainland Australia could meet the minimal conditions for the production of pongam. The suitable areas are mostly located in central north QLD extending to north of Tennant Creek in NT. Suitable areas could be significantly larger if expansion into the tropical rainforest of northern Australia is considered.
- Physic nut: about 23 Mha of the marginal regions were found to be suitable, mainly in the vicinity of Mt Isa in central-north QLD extending to north-east of Tennant Creek in NT, and in the regions south-west of Port Hedland in WA (Figure 2). Its production in WA is ruled out because its State Government has declared the crop a weed. There is some overlap of areas suitable for both physic nut and pongam.
- Indian mustard: this crop is much more frost-tolerant than either pongam or physic nut. Suitable areas for its production therefore extend as far south as southern NSW and north-central Victoria. In southern NSW and Victoria areas, they overlap with the grain belt, and may provide an option for the farmers, especially in the drier regions. It has been suggested that Indian mustard could offer some rotational benefits as a follow on from wheat, as it is deep-rooted, and has some biofumigant effects. It provides the best opportunity for expansion of biodiesel production in existing arable land and marginal areas of Australia because of its robustness and hardiness. Its limitation lies with the fact that it is an annual, rather than perennial, crop like pongam or physic nut, meaning its long-term production costs may be higher than for pongam and physic nut.

Other Potential Biofuel Crops

The next generation of biofuel production technologies will be capable of ethanol feedstocks production from crop residues, grass and trees (termed cellulosic feedstocks), but these technologies will probably not be viable for another 10 years (Kamm 2004; Kim & Dale 2005).

Table 2: Criteria used for assessing the suitability of marginal regions for the production of selected biofuel crops.

Crop	Temperature	Annual Rainfall (mm)	Soil	Plant Productivity Index
Pongam	• Minimum average July temperature ≥ 1°C • Average July frost days < 4	400–500	• Soil available water capacity > 85 • Soil nutrient status ≥ 0.75	2–10
Physic nut	• Minimum average July temperature ≥ 2°C • Average July frost days < 1	200–500	• Soil available water capacity > 45 • Soil nutrient status ≥ 1	2–10
Indian mustard	• Minimum average July temperature ≤ 3°C • Average July frost days < 10	300–400	• Soil available water capacity > 45 • Soil nutrient status ≥ 1	

Table 3: Potential marginal areas for the production of exotic biofuel crops.

	Approximate Locations of Suitable Regions	Area (Mha)	% Australia's Land Mass	% Australia's Current Arable Land
Pongam	Mostly in central north Queensland (QLD) near Mt Isa and Longreach, and areas north of Tennant Creek in the Northern Territory (NT). There is a substantial area east of Port Hedland in northwest Western Australia (WA).	20.06	2.6	40
Physic nut	Substantially in the area east of Mt Isa, extending north-west of the town to north-east of Tennant Creek in NT. There is a considerable area between Port Hedland and Newman in WA that is suitable for this crop.	23.47	3.1	47
Indian mustard	While some suitable areas for Indian mustard found in central north QLD and north-west WA overlap with the areas suitable for both pongam and physic nut, Indian mustard can be grown in areas as far south as southern New South Wales around Hay, extending into Victoria.	31.7	4.2	63

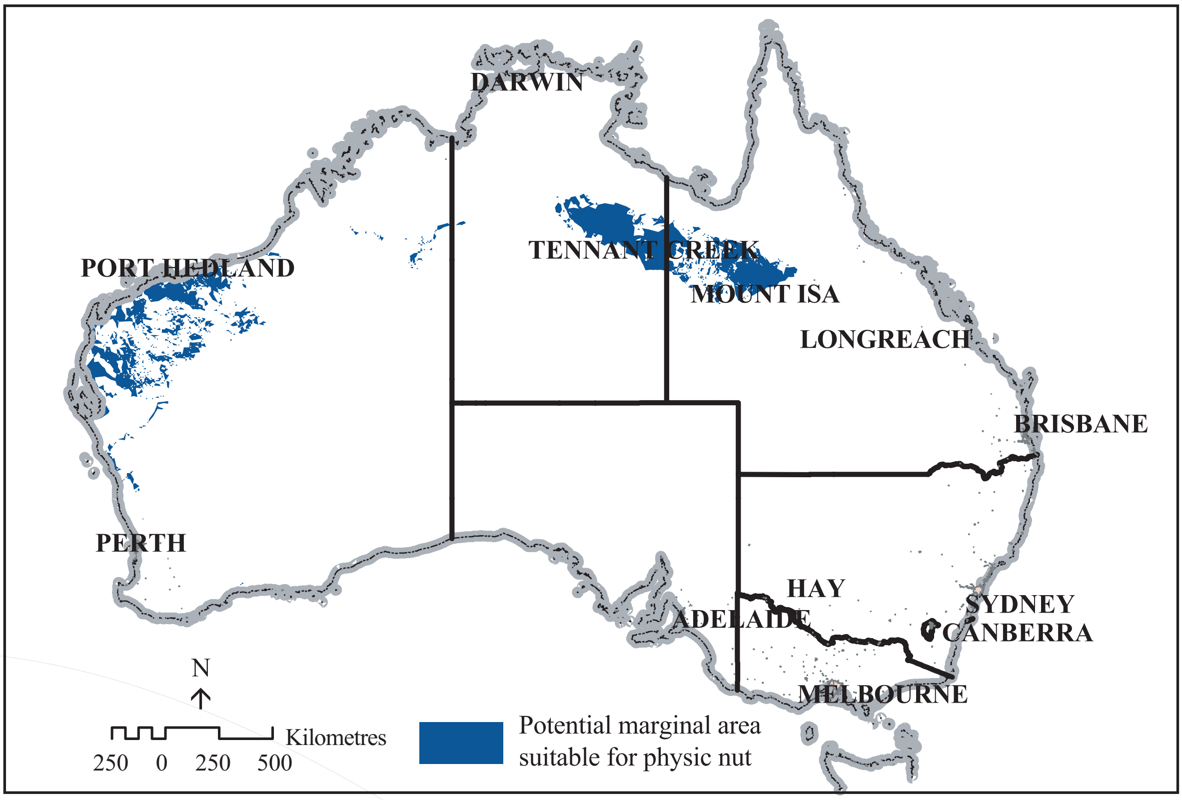

Figure 2: The marginal agricultural areas of mainland Australia suitable for the physic nut production.

Once these technologies are economically viable, it may be possible to harvest weeds (eg willow and poplar), tree plantations (eg mallee) and grasslands (eg Mitchell grasslands) for cellulosic ethanol production. There are also other potential oil crops such as *Azardica*, *Moringa*, *Simarouba*, *Madhuca*, *Sapindus*, *Calophyllum*, *Prosopis* and *Cynara*, but the environmental and agronomic requirements of these species are less well known (Azam et al. 2005; V Ghatty 2006, pers. comm., 16 June). There is also the possibility of producing biodiesel from algal oils, but the technology for this is probably still many years away (Minowa et al. 1995; Danielo 2005).

Environmental and Economic Benefits of Alternative Exotic Biofuel Crops

The benefits of biofuel crop production relevant to pongam, physic nut and Indian mustard, among the general benefits of biofuel crop production listed by the Australian Government's Biofuels Taskforce (2005), include:

- reduced emissions of greenhouse gases, as biofuel produced by these crops is either emission-neutral or produces low net emissions
- contribution to the Australian economy, either through import substitution or kick-starting a new industry
- improved energy security, as the national economy is less dependent on fuel importation
- regional employment, through new development in rural regions
- suitability for use in or near waterways and other sensitive environments where there is a risk of spills, because biodiesel – the product of these biofuel crops – is biodegradable and non-toxic.

Growing exotic biofuel crops such as pongam may also offer other benefits such as stabilisation and improvement of land over time. Additionally, the estimated potential marginal areas are located in regions of primary production (mining and grazing in northern QLD and northern WA) where biodiesel is most needed. Locating biofuel plants close to feedstock supplies will have a positive outcome for reducing the cost of fuel transport.

Some Caveats and Policy Implications

The results of this assessment should be viewed with caution. The assessment was based on input data of very broad spatial resolution – a one kilometre block size. Additionally, each layer of data used was highly uncertain; the effect of this uncertainty accumulating during the assessment. This means there is probably considerable uncertainty in the results. It is hard to determine whether the areas of suitability for each crop have been underestimated or overestimated. Therefore, a more detailed investigation specific for a given project is recommended, as local conditions may be at variant with the block estimates used in this assessment.

Although the policy implications of this assessment are beyond the scope of this paper, it should be noted that some of the conclusions reached are dependent on the government's excise for alternative fuels that is required to provide sufficient support to underpin the viability of the biofuel industry into the future. The challenge is whether the government's approach will provide enough incentives to encourage the development of new projects that will assist the industry to expand beyond current expectations and the prospective target of over 2,000 ML of biofuel production in the near future.

Conclusions

A major limitation to the expansion of Australia's biofuel production capacity is the lack of a reliable supply of domestic feedstocks. Diversion of existing crops (eg sorghum, wheat, canola, sugarcane) and arable land (eg grain belt) to produce biofuel feedstocks will compete with human food supply and livestock feed. Estimation of the suitability of the marginal and degraded agricultural regions for three exotic biofuel crops: physic nut, pongam and Indian mustard, indicates that up to 30 Mha of marginal agricultural land in Australia are potentially suitable. Pongam is a potential perennial tree crop in tropical areas of northern Australia (eg QLD, NT and WA). Indian mustard is potentially both a winter and summer annual crop in the marginal areas overlapping with the grain belt of southern Australia (eg NSW, VIC, SA and WA) and subtropical Australia (eg QLD and WA). However, potential for physic nut production may be limited due to it being declared a weed by the WA State Government.

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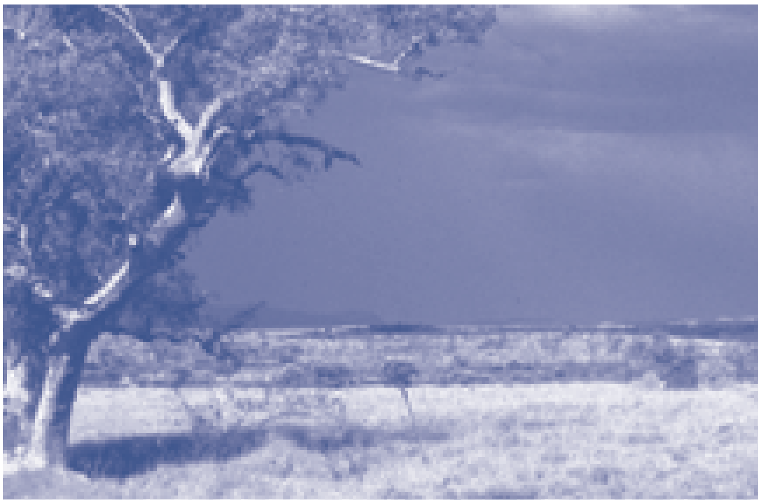

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