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Agricultural bioenergy cropping in Victoria – balancing the issues

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Abstract

There has been considerable interest in biofuels and bioenergy production (the generation of energy from biomass), as alternative agricultural industries for the future. High oil prices, diminishing total oil supply, the energy security debate, growing environmental awareness and the need to develop sustainable regional agricultural industries under climate change, are issues that are driving this interest. The Victorian Government, through its Agriculture and Fisheries Four Year Strategy, recognizes the benefits of developing a sustainable bioenergy industry, particularly using second generation biofuels. The development of a sustainable biofuel industry in Victoria may have a major impact on the Victorian economy by potentially: lessening the dependence on fossil fuels; enabling new markets and alternative income streams for farmers to be developed; developing new industries for regional Victoria; assisting in the reduction of greenhouse gas emissions; developing land management systems which provide efficient, low emissions energy sources, while reducing greenhouse gas (GHG) emissions. However, while bioenergy offers potential for significant benefits, it is critical that the economic, environmental (including weed risk, lifecycle GHG emissions and energy balance) and social values of any potential biofuel crop be fully assessed before its introduction and promotion.

Keywords: bioenergy, biofuel, biomass, bioenergy crops, sustainable, weed risk.

Introduction

Bioenergy is a form of renewable energy derived from conversion of biomass to electricity, heat and/or liquid fuels (biofuels) for transport via processes of combustion, fermentation or digestion. Bioenergy represents around 10 per cent of the world's primary energy consumption, although bioenergy has been less widely adopted in Australia, accounting for only 4% of Australia's primary energy consumption in 2007–2008 (but 78% of renewable energy use; Australian Government 2010). As a consequence of Government targets for renewable energy use, emissions reduction and other policies such as pricing carbon, bioenergy use in Australia is projected to increase by 2.2% per year to 340 petajoules in 2029–2030 (Australian Government 2010). Bioenergy in Australia is currently derived almost entirely from waste biomass with heat and electricity from bagasse, wood waste and gas capture from landfill and sewerage (anaerobic digestion), ethanol from sugar by products, waste starch and grain, and biodiesel from tallow, used cooking oil and oilseeds (e.g. dryland mustard). However, to meet the future demand for biomass, additional purpose grown sources will be required.

Discussion

The availability of reliable, consistent and sustainable biomass supply is critical to the development and expansion of the bioenergy sector (and indeed for the developing bioeconomy). First generation biofuel crops are those crops that contain either plant oil that may readily be extracted and converted into biodiesel, or starch or sugar that can easily be converted into ethanol by fermentation (e.g. maize, wheat, palm oil). Emergent 2nd generation (or later) technologies will be able to utilize a range of carbon sources, including lignocellulosic material found in the fibrous or woody material of plant crops, for conversion into liquid fuels (and as an alternative to combustion for heat and/or power). This creates new opportunities for both the use of the non-edible portion of food crops (including food processing waste) in addition to cultivation of non-food energy specific crops. Another aspect of biomass for bioenergy is the production of by-products and co-products. By-products can include precursors for the manufacture of industrial chemicals or products, or fermented product for animal feed. Co-products have intrinsic value as energy or for C sequestration (Johnson *et al.* 2007). For instance, the petrochemical industry is based on the carbon in oil, and typically makes as much money from the aliphatic and aromatic fractions that make up 3.4% of a barrel of crude oil as it does from the 71% that is devoted to fuels. It is expected the same will occur in the emerging bioeconomy (Allinson *et al.* 2007).

Biofuels and bioenergy production have been considered attractive alternative agricultural industries for the future in Victoria. High oil prices, diminishing total oil supply, the energy security debate, growing environmental awareness and the need to develop sustainable regional agricultural industries under climate change are key drivers. As production facilities are generally located close to feedstocks, the development of a healthy biofuels industry sector also represents important opportunities for rural and regional communities (a main policy driver for Government) throughout Victoria to benefit from the development of new industries, income streams, markets and sustainable growth (Government of Victoria 2007).

Victoria has an active bioenergy industry with established plants at scales ranging from farm/community through to industrial scale. There is significant community interest, with many Industry and Shire groups actively investigating bioenergy industry opportunities, and active interest from international technology companies to establish advanced bioenergy infrastructure in Victoria.

Two recent studies, conducted by the Future Farming Systems Research Division of the Department of Primary Industries (DPI) as part of the project 'Understanding the impact of current and future bioenergy production systems on the agricultural landscape', have identified: a range of bioenergy crops and their potential adaptation across Victoria under current (2007) climatic conditions and under future (2050) climate predictions (Rogers *et al.* 2010); and also bioenergy crops that could be grown on marginal (non-food producing) land in Victoria (Rogers *et al.* 2011). The focus of these studies was solely on mapping the potential of the crop to be grown in the Victorian climate. The crops were grouped into broad agronomic categories, e.g. cereal crops, oil crops, solid biofuel crops and starch crops. These studies did not take into account the potential yield of the species under the different environments, the weed potential, or the economics (such as the cost of production and processing) of growing these crops. In addition, the study examined each crop as a primary energy source, and did not take into account any potential bioenergy value that may be derived from waste or co-products, nor any costs or benefits to the ecosystem (such as improved biodiversity, water quality or carbon sequestration) that may incur when bioenergy crops are grown across Victorian environments.

An ideal bioenergy crop is one that is biomass derived, perennial, high yielding, and does not directly compete with food production (CAST 2007). This ideal crop preferably has a low input (water, fertilizer and cultivation) requirement and is adapted or adaptable, e.g. to a wide region across Victoria. Bioenergy crops that can act as break crops, and fit into existing farm systems allowing the farmer to double crop with food crops, will have an advantage for Victoria, although suitable areas in this class may be confined to irrigation or high rainfall areas. Equally, bioenergy crops that can be grown on degraded or poorly resourced land not suitable for food production (and therefore not at the expense of food production) also show potential. In general terms, leading bioenergy candidate crops for Victoria include:

- Native species that are adapted to marginal land, low rainfall and can be grown in a wide area across Victoria, both now and in the future, e.g. oil mallee (Turnbull *et al.* 2009) and salt bush, (*Atriplex* spp.);
- Perennial, high yielding grasses, e.g. switch grass, *Miscanthus*;
- Mustard (*Brassica juncea* vars) suited to low rainfall areas and with multiple uses;
- Canola (*B. napus* / *B. campestris*) where climate change predictions suggest that it could be grown across Gippsland by 2050;
- Jerusalem artichoke (*Helianthus tuberosus*) and safflower (*Carthamus tinctorius*) which are salt tolerant and therefore could be grown on marginal land;
- Sorghum (*Sorghum bicolor*) which has a lower rainfall requirement than other summer crops and is a multi-purpose crop;
- Camelina (*Camelina sativa*) which can be grown in degraded areas or otherwise marginal land;
- Summer crops which can be double-cropped with winter crops (such as soybean (*Glycine max*) and safflower).

Growing adapted bioenergy crops on marginal or under-resourced land is a potentially productive land-use option that avoids the food versus fuel debate as well as providing additional benefits in terms of the regeneration and rehabilitation of degraded land. There may also be multiple environmental benefits in terms of carbon sequestration and improvement in soil properties and wildlife habitat on the landscape scale. The bioenergy industry will likely be sustained mainly with non-native perennial species chosen for their rapid annual production of large amounts of above ground biomass, and low economic and environmental inputs (CAST 2007). Ideally, bioenergy crops should not be capable of surviving outside of highly managed agricultural systems (an ideal that is applicable to, but rarely achieved by all major crops). Potential bioenergy candidate crops identified for marginal land in Victoria include:

- Native perennial grasses, indigenous to Victoria, such as *Themeda* spp, *Elymus scaber* and *Microleaena stipoides* that are showing potential in terms of biomass production and are well-adapted to marginal conditions (Chivers and Raulings 2009).
- Native Australian shrubs and trees such as salt bush (*Atriplex* spp.), Mallee eucalypts and Casuarina species – again, plants that are well adapted to marginal land in Victoria.
- Introduced grass species such as *Arundo donax*, *Miscanthus* sp. that are versatile, salt tolerant (*Arundo donax*) and can be grown in a wide range of environments.
- Oil-bearing crops such as dryland mustard (*B. juncea* vars) and safflower that are suited to low rainfall areas and adverse soil types.

The purposeful introduction of a wide array of exotic plants to Australia has been essential for the successful development of a globally competitive agricultural industry. The economic benefits to Australia of these agricultural plants are generally accepted, but there have obviously been costs to the natural environment. It continues to be a challenge for Australian agricultural scientists to develop new, productive cultivars with limited weed risk. This challenge is no less for the emergent bioenergy industry. The application of stringent border weed risk assessment protocols since 1997 has substantially reduced the likelihood of new plant species posing a significant weed risk from entering Australia. However, there are over twenty thousand naturalized exotic plant species already present in Australia (Stone *et al.* 2008). Three criteria are often used to assess weed risk: invasiveness, impact and potential distribution. These criteria are equally applicable to 'post-border' weed risk assessments, i.e. assessment of naturalized exotic species for new agricultural purposes, e.g. bioenergy. Invasiveness can be characterized by a species' ability to establish in existing vegetation (and speed thereof), modes of reproduction and dispersal, its response to herbivory, and persistence of plant populations (Stone *et al.* 2008). One of the many weed risk assessment tools is to use information on a species' weediness in other locations as an indicator of high local weed risk. In this context it is important to note that native species can pose a significant weed risk outside their indigenous territory. Additionally, the potential impact of an agricultural plant on the establishment and yield of desired plants and on ecosystem services are considered. Finally an analysis of species' potential distribution is undertaken. From an agronomic perspective, the latter identifies the area in which a species could potentially be utilized. From an environmental perspective, this process can result in an estimate of the total area of native vegetation at risk if the species were to become a weed (Stone *et al*. 2008). Ultimately, however, a species' weed risk will vary according to its behaviour when challenged with local biotic and adaphic factors, under different climate change predictions and proposed cultivation systems, and these must all be considered when assessing the potential weed risk of bioenergy crops.

The giant reed (*Arundo donax*) is a good example of the different behaviour of a species in different environments. Although the origin of the giant reed is unknown, the consensus is that the species originates from Asia (most probably India), and has been cultivated for thousands of years throughout Asia, southern Europe, North Africa and the Middle East, and in the 19th Century was diffused widely in North and South America, and in Australia (Perdue 1958). This is a species having considerable potential as a highly productive biomass crop for pulp, paper, direct bioenergy and biofuel production in marginal lands (DM yields of >45 t ha^{-1} (Virtue *et al*. 2010); net energy production over 350 GJ ha^{-1} y^{-1} (Monti *et al*. 2009)). Some of the traits that make it an attractive agro-energy crop, e.g. fast growth rate, salt tolerance, rhizoidal propagation and rapid re-growth, limited number of pests, and the many potential uses for above ground biomass (Perdue 1958), will in some locations make it a potential weed. For instance, this plant is considered an invasive pest in the United States, being well established in riparian zones along warm, coastal freshwaters from Maryland to northern California (Bell 1997), and has the potential to become a localized weed under similar circumstances in Australia. However, this species has been present in Victoria for more than a hundred years, and there are now many small, isolated stands of giant reed dotted around the Victorian landscape (often associated with established homes or old homesteads where they may have been planted as ornamentals or wind-breaks). On the one hand, *A. donax* is considered by some to have high weed potential because of its rapid growth rate and vegetative competitive nature, while on the other hand studies of *A. donax*, have shown that it doesn't produce viable seed (and genetic studies indicate clonality) outside of south Asia and, because propagation is by rhizome splitting, it thus has limited ability to colonize wide areas – the principal risk for this species is via flood-mediated rhizome dispersion leading to invasion of riparian zones. In Victoria, *A. donax* is not listed as a noxious or invasive weed, nor was it considered an imminent risk by Victoria's Noxious Weeds Review undertaken by DPI (DPI 2007). Using the South Australian Weed Risk Assessment Management System (SAWRAMS), Virtue *et al*. (2010) suggest that the risk of cultivation of *A. donax* can be adequately managed through plantings outside areas subject to flooding, the use of buffer zones, annual surveys to detect and remove escapees, and hygiene protocols for harvest, transport and processing, made mandatory via noxious weed declaration. Permits and strict management conditions should then allow cultivation at low risk sites in the landscape.

Conclusion

While bioenergy offers potential for significant benefits, it is critical that the economic, environmental (including weed risk, lifecycle GHG emissions and energy balance) and social values of any potential biofuel crop be fully assessed before its introduction and promotion. Agronomic traits that make a species an ideal bioenergy crop can be similar to those that make introduced species invasive weeds. To date, the risk of invasion by species introduced for bioenergy production has received rather less attention than the benefits. All candidate crops need to be studied for invasiveness across a range of locations for both current and future climate scenarios. It is important that the benefits and risks are evaluated, and that management strategies are developed and communicated prior to the introduction of new biomass crops to ensure the emergent industry is both viable and sustainable.

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