Chapter 12
Environmental, Economic, and Social Impacts of Biofuel Production from Sugarcane in Australia

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12.1 Background

Sugarcane is one of Australia's largest crops and is grown over 565,000 ha (Agrifutures 2018; Commonwealth Australia 2010; Fig. 12.1). Sugarcane cultivation supports the production of raw sugar, ethanol, and green energy. Currently, around 4000 cane farmers grow sugarcane mostly on family-owned farms. The existing infrastructure such as mills, cane tramways, sugar export terminals, and water supply schemes for irrigation support the production of sugarcane leading to economic growth in the region (Department of Agriculture, Fisheries and Forestry 2013). It is expected, under the current demand for sugar worldwide, further significant expansion of sugarcane industry is possible, particularly through tropical Queensland, Western Australia, and the Northern Territory.

The sugarcane industry's major product is raw crystal sugar, which is sold to refineries both in Australia and abroad. Approximately 95% of Australian raw sugar is produced in Queensland with the rest from Northern New South Wales. Up to 35 million tons of sugarcane is grown each year. Over a season, the sugarcane crop can produce up to 4.5 million tons of raw sugar, one million tons of molasses, and ten million tons of bagasse (a fibrous cane residue that fuels boilers to cogenerate steam and electricity). Approximately 85% of the raw sugar produced in Queensland is exported, generating up to $2.0 billion in export earnings for Queensland (Australian Sugar Milling Council [ASMC] 2018).

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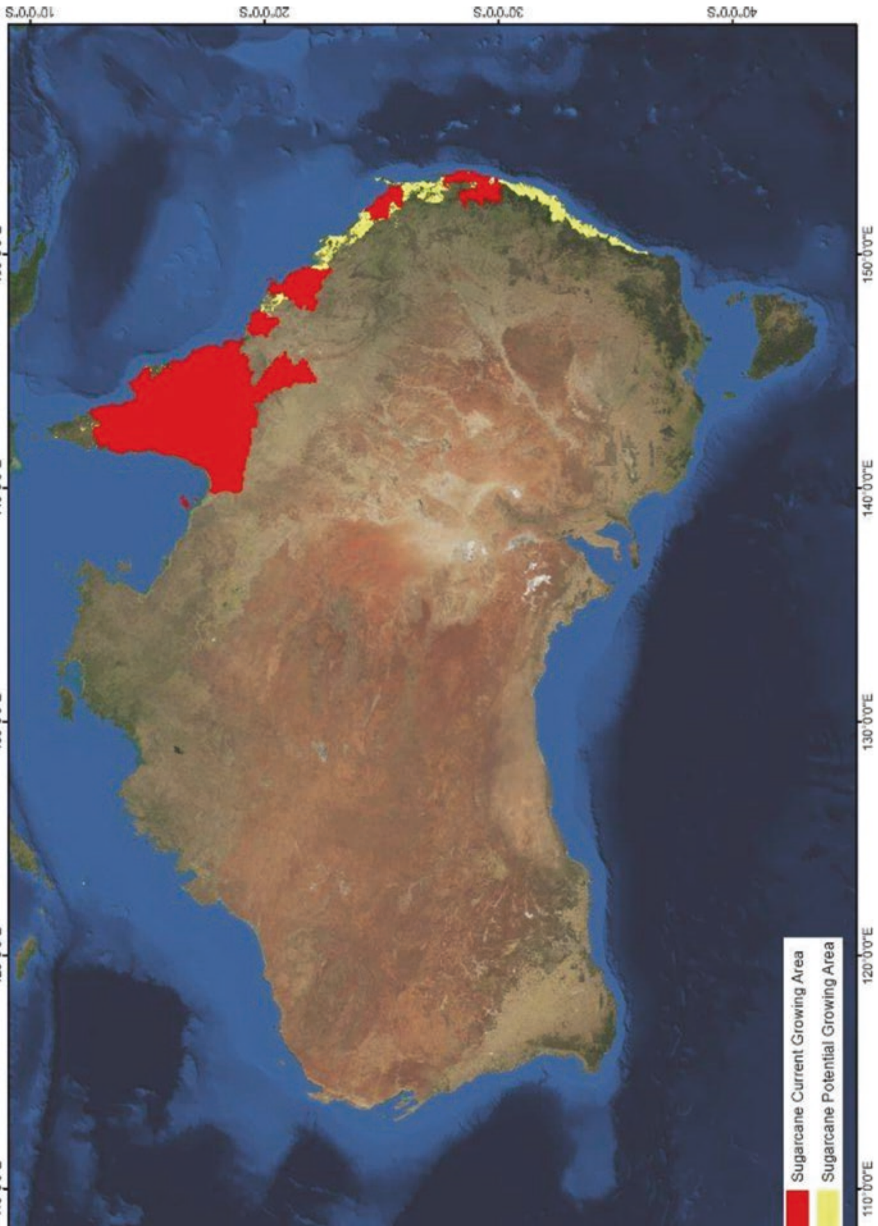

Fig. 12.1 Sugarcane production areas in Queensland and NSW. (Source: Agrifutures 2018)

Since sugarcane cultivation spans over such a large area (2200 km), its production is subject to various climatic and socioeconomic pressures. This chapter reviews some of the issues associated with sugarcane cultivation for sugar and bioethanol production.

12.2 Sugarcane Cultivation in Australia

Sugarcane farms are established through stem cuttings in Australia (setts/billets). Setts are planted in rows of 1.5 m and the crop is fertilized, often irrigated (40% of farms) and sprayed with herbicides (Fig. 12.2). The crop is harvested within 10–18 months of planting, mostly from June to December. One planting will last for 3–5 crop harvests. Australians have pioneered in cane harvesting technology and adapt "green cane" or "burnt cane" approach. In green cane harvesting, the cane is harvested along with the leaves, with the disposal of the leaves and the tops in the field. In burnt cane approach, the leaves are burnt and the stem is harvested. Cane harvesting is done mechanically using self-propelled harvesting machines to produce billets (or cut stems). The billets are loaded onto trucks or trains for delivery to the mills within a day or two. The farmer is paid according to the "cane payment system" which relies upon sugar content and the weight of the cane supplied (Sugar Notes 1997).

In the last 75 years, advances in sugarcane research have allowed the cane growers to maximize cane yields from 40 tons to 80–100 tons ha^{-1}. These advances

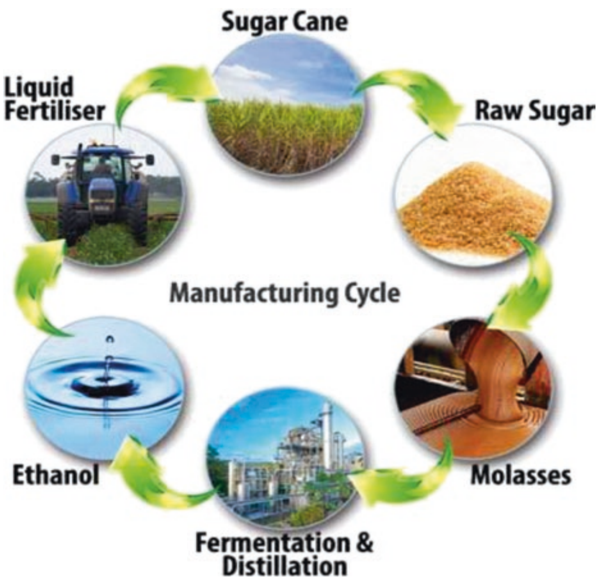

Fig. 12.2 Sugar and ethanol production cycle from sugarcane. (Source: Ethanol Facts n.d.)

include development of new cultivars (currently 70 cultivars are used), improved agronomic practices, pest and disease control, and harvesting and marketing technology (ASMC 2018). Long-term sustainability and reduction of adverse environmental impacts are the two important issues that bother sugarcane industry in Australia. Although sugarcane is a greenhouse gas neutral crop, it is a hungry crop requiring copious amounts of water and nutrients to achieve its maximum yield potential. Farmers will have to keep up with these inputs to achieve maximum yield. Application of heavy doses of fertilizers onto sandy to silty loam soils results in leaching of nutrients into creeks, rivers, and finally the Great Barrier Reef (Thornburn et al. 2011).

Several environmental programs are currently underway to find the means of minimizing nutrient leaching into the GBR, with the view to protecting the world-renowned natural heritage. The Australian government is spending millions of dollars to develop sustainable practices for sugarcane production. Some of these practices include new farm management practices, chemical accreditation training, water quality monitoring, trickle irrigation, integrated pest management, soil conservation, and restoration of wetlands and river banks. Promotion of green cane harvesting technology has helped immensely to minimize adverse environmental impacts (Duffy 2012).

12.3 Sugarcane Processing

Sugarcane production and its use in synthesizing various products are illustrated in Fig. 12.2. Once harvested, sugarcane must be milled within 16 hours to minimize degradation. Thus, cane crushing occurs 24 hours a day and 7 days a week for up to 22 weeks in a year. Australia has developed the most advanced technology to process sugarcane, and this technology is exported to other cane-growing countries as well. Sugar manufacturing begins with the shredding of billets to produce sugar juice and bagasse. The juice is pumped for further processing, and the bagasse is recycled as a fuel for the boiler (Khan et al. 2017). The juice is treated with lime and heated. This process results in clear juice and filter mud (dunder). The clear juice is concentrated by boiling to produce syrup. The syrup is again boiled and crystallized. This process is repeated, and the uncrystallized syrup is removed as molasses. The filter mud is used as a fertilizer, as it contains high concentrations of phosphorus. Molasses are either exported or used as stock feed. They are also used in distilleries to synthesize industrial alcohol (ethanol), rum, and carbon dioxide.

Sugar manufacturing results in a variety of by-products. These include bagasse, filter mud, and molasses. Bagasse is used as a source of fuel and it adds 20 megawatts of power to Queensland's electricity grid (Bioenergy Australia 2018). The ash and filter mud are used in sugarcane cultivation, and hence they will return some proportion of the nutrients removed from the cane fields (Sugar Notes 1997).

12.4 Potential of Ethanol Production

Ethanol produced from sugarcane has the potential to meet a very significant proportion of Australia's current automotive gasoline requirements. In a possible moderate ethanol production scenario that includes trash collection and cellulosic ethanol production, sugarcane has the potential to provide sufficient ethanol to meet 14% of Australia's (or 61% of Queensland's) automotive gasoline requirement while not consuming any additional coal or other supplementary fuels (Global Agricultural Industrial Network [GAIN] 2017). Through crop expansion or the coprocessing of other renewable fibers (such as sweet sorghum or green waste), further ethanol production may even be possible. Higher ethanol production quantities are also possible with the cultivation of higher biomass sugarcane varieties and the cultivation of varieties with a higher proportion of total fermentable sugars (GAIN 2017). According to the Audit report by the Queensland Department of Agriculture, Forestry and Fisheries, Queensland has the potential to increase the land use for sugarcane from 0.33% to 4.06%. This means in Queensland, there is an enormous opportunity for growing sugarcane. Based on the technology of using waste resources for growing algae, cane growing and sugar processing can also occur to produce biofuels (Prasad et al. 2014).

12.5 Refineries

Bioethanol production mostly occurs at three major refineries in Australia (Bureau of Resources and Energy Economics 2014). These facilities are located in Queensland (Sarina and Dolby) and NSW (Nowra). Australia produces 1.3 million tons of refined sugar annually, which is used nationwide or exported (ASMC 2018; Bioenergy Australia 2018). In 2012, Australia produced 440 million liters (ML) of ethanol. Around 68% of this occurs in NSW and is produced from waste wheat starch. The Dolby refinery uses sorghum to produce 80 ML of ethanol from sorghum. The Sarina refinery uses molasses from sugarcane and it generates 60 ML of ethanol annually (Rural Industry Research and Development Corporation [RIRDC] 2018). Sarina refinery is ranked as the most energy-efficient refinery in Australia, as it uses sugarcane bagasse as the energy source for ethanol production (co-generation) (Farrell 2014). An additional 90 ML of ethanol could be produced, if all exported cane molasses produced in Queensland could be used in ethanol production (O'Hara 2010). In 2017, the total biofuel production in Queensland alone was 290 million liters, including 250 million liters of ethanol and 40 million liters of biodiesel.

12.6 Policies and Regulations

In Australia, ethanol is blended into regular petroleum products and marketed as E10 (10% ethanol) which is currently mandated in Queensland and New South Wales (NSW). In 2001, the Australian government tried to introduce voluntary national biofuel target of 350 ML per annum by 2010. The Queensland government then attempted to introduce 5% ethanol (on average), but this bill was rejected in October 2014 due to uncertainty in fuel excise regime.

Later, Queensland passed the Liquid Fuel Supply (Ethanol and Other Biofuels Mandate) Amendment Bill in December 2015, according to which 3% ethanol was mandated for all petrol sold in Queensland. This became effective from January 1, 2017, with the intention of increasing the mandate to 4% ethanol after 18 months (Department of Natural Resources Mines and Energy 2015). For example, if 4 out of every 10 liters of regular petrol sold by a petrol station (or group of petrol stations) were E10, which contains 10% ethanol, the fuel retailer would have complied with the bio-based petrol mandate. A key objective of this amendment of course was to deliver a net greenhouse gas benefit compared to regular fuel. It was expected that more motor vehicles would use petrol with ethanol and thereby reduce the greenhouse gas emission. In addition, petrol stations were advised to take necessary action to make available ethanol-mixed petrol to drivers.

The government rebates have been introduced to promote biofuels in Australia. For example, federal government introduced Ethanol Production Grants (EPG) in 2008. This program provided a rebate of 38.143 c L^{-1} fuel excise for domestically produced ethanol used in the transport sector. The EPG was introduced to protect local ethanol industries against cheap imports and to encourage the community to use ethanol as an alternative transport fuel (Australian Government Department of Industry 2014). However, bioethanol production declined by 17%, despite the EPG scheme. The EPG program was finally closed in June 2015. Simultaneously, the excise was also removed for 1 year. From July 2016, the fuel excise was increased by 6.554% each year until it reaches 12.5 c L^{-1} in July 2020 (Biofuel Association of Australia 2014). At this stage, a subsidy of 25.643 c L^{-1} will be provided while the imported fuel will still be subject to an import duty of 38.143 c L^{-1}.

12.7 Other Feedstock Options for Australia

Second-generation biofuels such as energy crops and algae-based fuels have been successfully demonstrated, but there is no commercial production, and no subsidy schemes are being offered for commercial sales. A significant research effort has been initiated by a number of research agencies in the development of first-generation and second-generation biofuels (RIRDC 2018). The Queensland government has recently announced a number of programs aimed at making the state a center of biomanufacturing and biofuel production. It also hopes to develop the commercial production of biofuels for military, maritime, and aviation uses (GAIN 2017).

In addition to sugarcane, other lignocellulosic biomass is considered for bioenergy production, including forest residues of both hardwood and softwood timber which form number one significant source (e.g., eucalypt and pine residues). Agricultural wastes such as sorghum straw, rice straw, wheat stubble, corn stover, and sugarcane bagasse (O'Hara 2010) are also used. Furthermore, cultivation of perennial grasses such as Napier grass (*Pennisetum purpureum*), *Miscanthus* sp., and giant reed (*Arundo donax*) is investigated exclusively for biofuel production.

Australia has diverse climatic conditions ranging from temperate to subtropical and tropical climates. Region-specific species must be tested for biofuel production. Consideration should also be given to using native species such as brigalow and the exotic weeds (e.g., camphor laurel, *Mimosa pigra*, and *Acacia nilotica*) that use low water and nutrients (1200 mm of seasonal water and a nitrogen requirement of 120 kg ha^{-1} $yr.^{-1}$). The highly water-use-efficient plant such as agave is also being field-tested for bioethanol production (Holtum and Chambers 2010; Rijal et al. 2016a, b).

12.8 Impacts of Biofuel Production from Sugarcane in Queensland

One of the primary justifications for a shift to biofuels as an alternative source of energy has to do with climatic benefits that are anticipated to occur from the substitution of fossil fuels whose combustion results in large net greenhouse gases emission (German et al. 2011). Of the possible sources of bioethanol, sugarcane crops are the most land-efficient crops in replacing fossil energy, and here in tropical Queensland, sugarcane significantly outperforms sugar beet grown in temperate regions, as it produces up to 8 units of energy per unit of petrol energy used (Wikipedia Contributors 2018).

Although biofuel production remains small in the context of total energy demand in Australia, it is significant in relation to current levels of agricultural production. The potential environmental and social implications of its continued growth must therefore be recognized. The reduction of greenhouse gas emissions are among the explicit goals of some policy measures to support biofuel production. Unintended negative impacts on land, water, and biodiversity count among the side effects of agricultural production in general, but they are of particular concern with respect to biofuels, for example, the production of bioethanol and biodiesel from sugarcane. The extent of such impacts depends on how biofuel feedstocks are produced and processed, the scale of production, and, in particular, how they influence land-use change, intensification, and international trade (Food and Agricultural Organization 2012).

12.9 Impacts on Climate Change

One of the primary justifications for a shift to biofuels as an alternative source of energy has to do with the climatic benefits that are anticipated to occur from the substitution of fossil fuels, whose combustion results in large net emission of CO_2, to fuels whose combustion gases are sequestered through cultivation and thus are considered as greenhouse gases (GHGs) neutral (Macedo et al. 2008; Peters and Thielmann 2008). This promise of greener energy for transport has led to the inclusion of biofuels in alternative energy targets in many industrialized countries, notably the USA and the EU, Australia, Canada, and a growing number of developing countries, notably Brazil (Petrolworld 2008).

Ethanol-blended fuels have been shown to produce lower concentrations of GHG than fossil fuel, proving to be a superior, more sustainable fuel in the long term, and thus encouraging the introduction of even more blend combinations to the market (Department of Environment and Energy 2018a). The government reviewed its climate change policies in 2017 to ensure low emission in various sectors including electricity sector. It is to be noted that Australia's emissions for the year to March 2018 were 1.9% below the emissions in 2000 (547.0 Mt. CO_2-e) and 11.2% below the emissions in 2005 (604.7 Mt. CO_2-e). Electricity sector emissions have declined by 13.9% (29.2 Mt. CO_2-e) in the year to March 2018, from the peak recorded in the year to March 2009 (Fig. 12.3). At the same time, emissions per capita were at their lowest levels in 28 years. Emissions per capita in the year to March 2018 have fallen 36% since 1990 (Department of Environment and Energy 2018a).

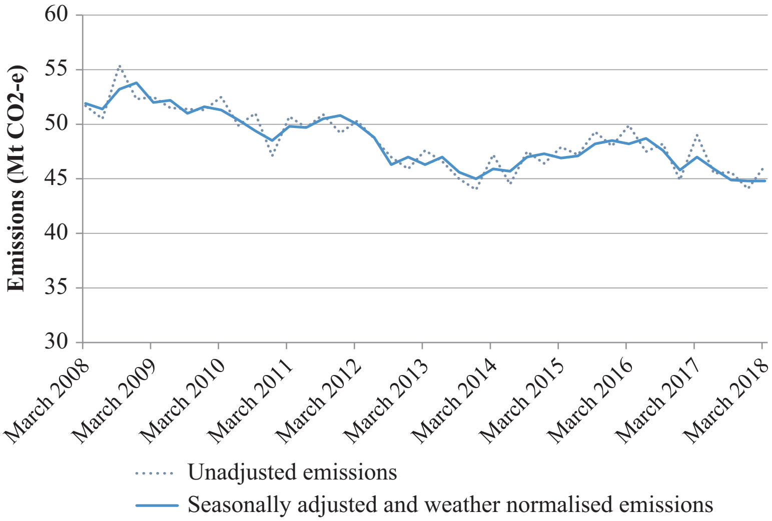

Fig. 12.3 Emission from electricity sector by quarter, Australia, from 2008 to 2018. (Source: Department of Environment and Energy 2018a)

The emission projections show that Australia continues to make progress in reducing emissions (Fig. 12.3), for example, in the electricity sector. Considering the climate change, the government is gradually reducing reliance on coal and increasing renewable generation. The renewable energy generation, for example, has increased by 12% in 2015–16, comprising 15% of total generation in Australia. Renewables continued to grow strongly in the calendar year 2016, to reach more than 16% of total generation. Although other sources such as hydropower and solar are the main sources of renewable energy, the production of biofuels in Australia as a whole and the Queensland state in particular is increasing. Among all the states in Australia, biofuel generation in Queensland is higher than in any other states (Department of Environment and Energy 2017).

In Australia, the transport sector requires more than 1.4 billion liters of fuel each year. The government had intended to produce at least 5% of the total transport fuel from biomass together with the net reduction of 3.5 million tons of carbon from Australia's net annual GHG emission. The emission of GHGs in CO_2 equivalent from the total petroleum fuel production and fuel use in Australia is approximately 120 million tons each year (Department of Environment and Energy 2017).

Bioethanol produced from sugarcane is environmentally friendly, particularly concerning the reduction in GHG (NO_x, SO_x, CO_x) emission. The use of bioethanol to reduce NO_x is attractive for several reasons. First, bioethanol contains little nitrogen, as compared to the diesel fuel. Second, bioethanol contains virtually trace amount of sulfur, so SO_x emissions are also decreased in direct proportion to the petro fuel replacement. When a petro fuel is replaced by a biofuel, there is a net reduction in CO_x emissions also (Demirbas 2009). It is estimated that bioethanol can save 41% (Tilman et al. 2006) to 52% of GHG emission as compared to petroleum-based fuels. Bioethanol is also known to reduce particle mass emissions by 57% (United States Department of Agriculture [USDA] 2017).

12.10 Biophysical Impacts

While biofuel potentially reduces GHG emissions, some studies suggest that the emissions associated with direct and indirect land-use change alone may negate estimated climatic benefits, particularly when biofuels displace carbon-rich ecosystems and effect food production (Lapola et al. 2010; Pleven et al. 2010). Within scientific and policy circles, it is increasingly recognized that adequate accounting of the effects of biofuels must consider the full life cycle of the bioenergy production, distribution, and consumption chain, as well as direct and indirect land-use changes associated with biofuel feedstock cultivation (Fritsche et al. 2011; Pena et al. 2010).

In the context of Queensland, the effect of sugarcane cultivation in the surrounds of Great Barrier Reef (GBR) has been a great concern (Waterhouse et al. 2012). Most of the sugarcane fields in Queensland are situated along the GBR catchment area. The chemical Diuron is widely used in the GBR catchment as a herbicide and has been described as essential for growing tropical crops like sugarcane (Duffy 2012). The sugarcane industry is the third largest user of Diuron in Australia, and this crop is largely grown in the GBR catchment (Holmes 2014a, b). Diuron is particularly damaging to the GBR and has been detected within the catchments and waters of the GBR. When released into waters, Diuron can reduce the ability of the coral ecosystems to photosynthesize. Diuron has also been shown to have adverse impact on sea grasses, mangroves, corals, and other species (Jones et al. 2015).

Other sources of agricultural pollution in the GBR region include the use of herbicides like atrazine and hexazinone and the increased use of fertilizers containing nitrogen and phosphorous. Dissolved inorganic nitrogen (DIN) from sugarcane farming is particularly a significant problem (Waterhouse et al. 2012). DIN is released from many regularly used fertilizers, and it increases organic matter in the planktons and sediments leading to higher outbreaks of coral disease and the invasive "crown of thorns starfish" (Waterhouse et al. 2012). DIN from the three *priority catchments* was recently reported to be the number one priority pollutant affecting water quality in the GBR (Davis et al. 2013).

It is to be noted that 85% of sugarcane production in Queensland is concentrated in three catchment areas: the Wet Tropics, Burdekin Dry Tropics, and Mackay-Whitsunday regions (Smith et al. 2014). These are often referred to as the "priority catchment areas." A study conducted in 2012 found that the use of nitrogen fertilizers in these three areas was a top priority for policy management to address (Waterhouse et al. 2012). Furthermore, sugar mills produce waste water, emissions, and solid waste that impact on the environment. The massive quantities of plant matter and sludge washed from mills decompose in freshwater bodies, absorbing all available oxygen leading to massive fish kills. In addition, mills release flue gases, soot, ash, ammonia, and other substances during processing (Waterhouse et al. 2012).

Another issue of concern is the fact that land laid bare in preparation for cane planting is stripped of any protective cover, allowing the soils to dry out. This affects microbial diversity and mass, both of which are essential to maintain soil fertility. Additionally, exposed topsoil is easily washed off from the sloping land, with nutrients leached from the topsoil. Furthermore, the continual removal of cane from the fields gradually reduces fertility and forces the growers to rely increasingly on fertilizers (Puri et al. 2012). In general, production of ethanol would provide greater benefits if their biomass feedstocks can be produced with reduced inputs (i.e., less fertilizer, pesticide, and energy), were producible on land of low agricultural value, and required low input energy to convert feedstocks to biofuel (Puri et al. 2012).

Akbar et al. (2018) list factors that limit commercial production of ethanol: (i) additional pressure on prime agricultural land, (ii) food vs fuel and biodiversity issues, (iii) adverse environmental impacts, and (iv) costly feedstocks. They also stated that inconsistency in the support of both federal and state governments also curtail the commitment of entrepreneurs who endeavor to invest in biofuel production facilities. For example, NSW government has mandated 6% bioethanol and Queensland government 4% ethanol (Fair Trading NSW 2015; USDA 2017). However, the other states have not shown support. It is also uncertain if the above mandates would be changed with the changes in the ruling parties of the governments, as has occurred in the past. Lack of government subsidies to start large-scale production plants is another constraint for promoting bioethanol production in Australia. The lack of Australian Government's action to penalise the fuel companies those fail to comply with the mandated bioethanol use is an important issue. This is discouraging the entrepreneurs who are keen to invest in biofuel production facilities.

A reef protection regulation was introduced by the Government of Queensland recently to ensure best practice farming by sugar industries and thereby protecting the biophysical impacts. There are a number of programs and support tools that help cane farmers adopt best farming practices. The government has initiated "*The Smartcane Best Management Practice (BMP)" program* which is an industry-developed, robust, and practical system that deals in improving productivity, profitability, and sustainability of farm enterprises. Through the Smartcane BMP, cane growers self-assess their practices to determine if they are "below," "at," or "above" the industry standard. Adopting practices for effective nutrient management can improve farm productivity and profitability, and reduce nutrient losses to the reef (Queensland Government 2018). It is expected that cane farming biophysical impacts will be reduced, thereby adding more value to the GHG reduction.

12.11 Social Impacts

In addition to environmental impacts, it is equally important to analyze the trends of social impacts of sugarcane ethanol industry. The study on the life cycle analysis of ethanol indicates that there are various social impacts that affect more than one group of actors. These issues, which are crucial in the debate surrounding the social sustainability of sugarcane in general, include energy security, compliance with legal framework, law enforcement, employment and income generation, public participation, public acceptance of biofuel, and health impacts. Energy security constitutes one of the main driving forces behind the biofuel development policies in Australia and elsewhere in the world (Rossi and Hinrichs 2011; Selfa et al. 2011) as one of the benefits of biofuels would be to reduce dependence on foreign energy at the national level (Sobrino et al. 2010). In addition, there is evidence that biofuel production has increased energy security at the household level and local level through the implementation of small-scale projects (Gasparatos et al. 2011).

Landholders surrounding sugarcane fields and particularly fishermen who depend on fishing for livelihood can be affected adversely, leading to loss or reduction of income. Social inequality may arise at local, regional, and national levels. There need to be a strong and comprehensive regulation and guideline to address these social issues in biofuel as well as the ethanol sector (Sawyer 2008). The cumulative negative social impacts of the ethanol industry could damage its social-political legitimacy (Hall et al. 2011), if there is not a sturdy legal framework for biofuel development and active law-enforcement mechanisms. However, one of the positive social impacts is that the development of biofuel programs can create jobs in rural areas, and along the overall productive chain, from research to trade and services (Neves 2010).

The role played by the bioethanol and biodiesel productions in job creation in Queensland has not yet been determined comprehensively. However, evidences show that labor forces are required from sugarcane production to biofuel synthesis and its marketing. In Australia, ethanol industry is usually characterized by centralized, large-scale, and export-driven production. This model is less labor-intensive since it is based on mechanized harvesting and involves higher rates of temporary, unskilled employment at the farm level (German et al. 2011). In Brazil, for example, one single machine in sugarcane harvesting can displace 80 workers (Smeets et al. 2008). However, temporary jobs are created during the construction of the processing plant, while jobs at the refinery would demand unskilled and highly skilled laborers (Bell et al. 2011).

Community acceptance and community engagement are other issues of social impacts in the biofuel sector. Community acceptance of biofuels varies among different geographical contexts, and previous studies do not offer conclusive results on the subject, particularly in the context of Queensland. This requires study of the community acceptance on ethanol production. A study on the stakeholders' perception about sugarcane industry indicated that the stakeholders (farmers) were not interested in engaging their next generation in the sugarcane sector. With this in view, ethanol production could face public resistance in the future, if technology does not advance as forecasted, that is, developing cellulosic ethanol with improved cost and environmental efficiency (Luk et al. 2010). Consumer acceptance of ethanol or biodiesel depends mainly on the price and supply stability.

Communities surrounding the sugarcane fields may be concerned about a number of aspects such as changes on aesthetics, concentration of incomes by large-scale firms, and feedstock transportation constraints among others (Rossi and Hinrichs 2011). Local communities from ethanol-producing regions may show low levels of satisfaction regarding economic benefits or poverty reduction resulting from the presence of ethanol plants as well as concerns about traffic problems and risks of instability or decline of industry in the future (Hill et al. 2006; Selfa et al. 2011). In this regard, changes in and expansion of infrastructure related to ethanol projects also need the appraisal and acceptance of local communities in the context of Queensland as well as Australia. Overall, community engagement in decision-making relating to biofuel production projects enhances the awareness of both negative and positive aspects and thereby fostering implementation of more sustainable projects from social and environmental points of view.

Fuel ethanol producers are concerned about sustainability of increasing the area under cane production for the purpose of fuel ethanol production. This is because all productive land has been utilized, and hence further production can only occur on lands that are not as productive as the ones being used. The implication of this scenario is that the farmers have to use larger areas of land to obtain the same yield, if additional production is to occur on the land other than that being used at present due to lack of irrigation, lower rainfall, or the need to use less fertile soils (Akbar et al. 2018).

The area of land for growing sugarcane has gradually increased from 366,000 ha in 2007 to 377,000 ha in 2017. Likewise, the total production of sugarcane has increased from 34 million tons to 38 million tons. The land coverage for sugarcane production and harvesting is increasing and therefore offering a potential risk of disputes with land rights and land-use pattern (ASMC 2018). Conflicts in land rights happened in Thailand, one of the top sugar-producing countries in the world (Sawaengsak and Gheewala 2017). One of the main concerns about expanding sugarcane industry in Queensland, linked to the prominent role of industrial-scale plantations, is its effects on local land rights. Particularly, the indigenous people with traditional claims to land are likely to be disadvantaged by sugarcane farming expansion as formal recognition of their claims is limited in practice in Queensland. In Queensland, where 7% of Aboriginal people of total population live, local land rights is an important social issue.

To follow the mandate of the Queensland government regarding the use of biodiesel and bioethanol for transport, more land for sugarcane production would be needed. Other farmers, such as livestock and fishermen will be affected due to the expansion of land for sugarcane cultivation. In addition, the fishermen will be affected given the quality of water in the river in the catchment area and creeks might be deteriorated and therefore impact the fish stock. It can be clearly assumed that there will be both positive and negative social impacts of biofuel production from sugarcane (German et al. 2011; O'Hara 2011).

12.12 Economic Impacts

The gross value of production of sugarcane to the Queensland economy in 2013–2014 was $1.165 billion which represents about 10% of the total value of all agricultural production in Queensland. The sugar industry is therefore incredibly significant to Queensland and Australia's economy. The economic impacts of biofuel production include job creation or flow of labor force and income generation by farmers, income of laborers, and the overall impact at the regional and national levels. The cost of large-scale production of bio-based products is currently high in developed countries. For example, the production cost of biofuels may be three times higher than that of petroleum fuels, without, however, considering the non-market benefits. Conversely, in developing countries, the costs of producing biofuels are much lower than those in the OECD countries, including Australia which is very near to the world market price of petroleum fuel (United Nations 2008).

Importantly, economic advantages of a biofuel industry would include value added to the feedstock, an increased number of rural manufacturing jobs, an increased income tax, investments in plant and equipment, reduced greenhouse gas emissions, reduced reliance on crude oil imports, and supported agriculture by providing a new labor and market opportunities for domestic crops. In recent years, the importance of nonfood crops has increased significantly. The opportunity to grow nonfood crops under the compulsory set-aside scheme is an option to increase biofuel products (Roebeling et al. 2007).

A case study for Sarina ethanol generation and sugar production facility showed that the plant created 36 permanent jobs and 222 flow-on jobs, 389 construction direct jobs, and 256 flow-on jobs, adding $7.7 million to the household income in the region. However, caution is required in extending the results more broadly across regions, as these data do not take into account potential impacts on associated industries (Commonwealth Scientific and Industrial Research Organization [CSIRO] 2007). Nevertheless, it is important to underline the cost-effective and cooperative management strategies to preserve the livelihoods of thousands of cane farmers and the economic sustainability of their industry.

The major disadvantage of fuel ethanol, however, is its production cost. The production cost per liter of ethanol is still high compared to that per liter at current world crude oil prices for unleaded petrol. Consequently, the production of ethanol requires government assistance to be competitive even for larger producers. A study by the Australian Bureau of Agricultural and Resource Economics found that the production of ethanol is not commercially viable in Australia without government assistance for achieving the associated environmental and social benefits (Cochran et al. 2010).

12.13 Conclusion

Sugarcane production has been a significant activity in Queensland. This activity is being extended to Northern New South Wales and Western Australia, due to increased interest placed on the use of by-products of sugar production. As a consequence, the area under sugarcane cultivation is constantly expanding. This expansion includes both positive and negative environmental, social, and economic impacts. The positive impacts include increasing Australia's capacity to synthesize its own fuel with the view to reducing fuel imports and to providing cleaner environment (e.g., reduced emission and limited soil contamination). In addition, the expanded sugarcane cultivation will provide incentives to younger generation to not to move out of rural areas, thus ensuring long-term sustainability of sugarcane farming. The negative effects include nutrient leaching into the Great Barrier Reef (Coast protection), pollution of water in the GBR, impacts on native title, and reduction in the productive capacity of cane fields due to running-off of nutrients. To address the negative impacts, the Queensland government with the support of the Government of Australia has taken initiatives to minimize negative impacts and maximize the benefits of sugarcane farming. The federal and Queensland governments have introduced programs such as GBR Foundation Partnership (Department of Environment and Energy 2018b, Reef CRC, Queensland's Biofutures Program and Smartcane BMP (Queensland Government 2018). The Australian government has established the Reef Trust to improve water quality, restore coastal ecosystem health, and enhance species protection in the Great Barrier Reef World Heritage Area. The government has also established GBR foundation in 2000 in response to the UN World Heritage Convention to protect the GBR heritage site. The GBR Foundation partnership is the collaboration of Reef Trust and the GBR foundation administered by the Department of Environment and Energy. The ultimate aim of the GBR Foundation Partnership is to implement key actions and achieve key outcomes of the joint Australian Government Reef 2050 Plan (updated) which was released in July 2018. Hopefully, intensive programs that the federal and Queensland governments are introducing (GBR Foundation Partnership, Reef CRC, Queensland's Biofutures Program) will help find suitable solutions to minimizing the negative impacts of sugarcane cultivation for biofuel production and enhance its production and role as a biofuel source in the country.

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