Chapter 15
Sugarcane Biofuel Production in South Africa, Guatemala, the Philippines, Argentina, Vietnam, Cuba, and Sri Lanka

Mohsen Mandegari, Abdul Muhaymin Petersen, Yuda Benjamin, and Johann F. Görgens

15.1 Introduction

Substantial sugarcane industries exist in South Africa (SA), Guatemala, the Philippines, Argentina, Vietnam, Cuba, and Sri Lanka. Despite not being the largest from a global perspective, these industries still have significant footprints in agriculture and rural economic development of these countries. A diversity of activities occur in the sugarcane value chain, from agriculture through transport and the manufacture of raw and refined sugar, syrups, and specialized sugar by-products and coproducts. The sugarcane industries in these countries have potential to contribute significantly to bioenergy and biofuel production. The present chapter considers the situation in each of these countries with regard to biofuel and electricity coproduction from sugarcane.

M. Mandegari · A. M. Petersen · J. F. Görgens (✉)
Department of Process Engineering, Stellenbosch University, Stellenbosch, South Africa
e-mail: jgorgens@sun.ac.za

Y. Benjamin
Department of Industrial Development, Ministry of Industry, Trade and Investment, Dar es Salaam, Tanzania

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15.2 South Africa

15.2.1 Status of the Sugarcane Crop in the Country

Sugarcane is a strategic agricultural crop for South Africa with a production capacity of more than 20 million tons per annum. Sugarcane is grown by approximately 24,000 registered sugarcane growers farming predominantly in KwaZulu-Natal with substantial operations in Mpumalanga, and some sugarcane production in the Eastern Cape. Sugar is manufactured by six milling companies with 14 sugar mills operating in the cane-growing regions. The industry produces an average of 2.2 million tons of sugar per season (March–December). Approximately 75% of this sugar is marketed in the Southern African Customs Union (SACU), while the remainder is exported to markets in Africa, Asia, and the United States, as reported by South African Sugar Association (SASA 2017).

The 10-year (2006–2016) trend of sugarcane production and area harvested based on the reported data by the Food and Agriculture Organization (FAO) are shown in Fig. 15.1. A considerable decrease can be seen in annual production and harvested areas, mostly due to changes in rainfall. For instance, 2015/2016 season was affected by the severe drought experienced in Southern Africa. The season was extremely poor in terms of tons of cane harvested, which decreased by 16% from 2014 to 2015 and 26% since 2013 to 2014 (Smith et al. 2016).

Currently, South Africa is the world's 18th largest sugar producer, with sugar being the second largest agricultural export. In 2006, South Africa was ranked at the 14th position in the world (FAOSTAT 2017). The lower production rate is not only because of severe drought but also inefficient performance of the sugar mill factories (Dogbe et al. 2018).

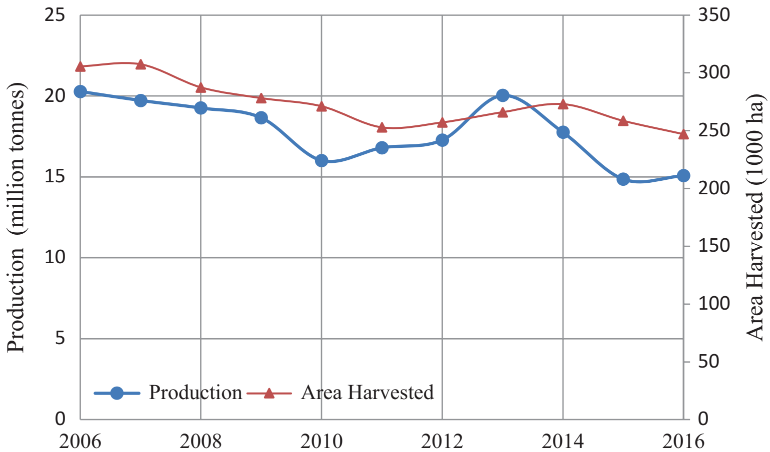

Fig. 15.1 Trend of sugarcane production and area harvested in South Africa during 2006–2016. (FAOSTAT 2017)

In addition to sugar, molasses and bagasse are the other by-products from sugarcane produced in typical South African sugar mills. Molasses contains considerable amounts of sucrose (approximately 32–42%), and can be sold in liquid or dried form as a commercial feed ingredient. Sugarcane molasses is also used for alcohol production; moreover, the distillery process yields vinasses that find applications in fertilizer production or animal feeding. Sugarcane molasses has several important roles in livestock feeding, due to the nutritive, appetizing, and physical properties of its sugar content. Molasses is difficult to handle because of its viscosity: it is rarely fed directly in its liquid form but instead mixed with other ingredients such as bagasse (Feedipedia 2018).

Sugarcane bagasse (fibrous fraction of cane after sugar extraction) is the most abundant crop residue produced globally and this resource can be increased by harvesting the sugarcane leaves and tops. Typically 15% of sugarcane is bagasse (dry matter), and leaves account for additional 7.5% of the biomass (Petersen et al. 2014). The use of sugarcane harvesting residues (mostly brown leaves; also called trash) has the added benefit of not competing as a food source and has a similar energy content as bagasse per unit weight. However, trash is frequently burnt off to facilitate harvesting of the stalks, thus not realizing its potential as a significant source of energy.

15.2.2 The Sugar Industry of the Country

Statistics South Africa (STATSSA 2018) reports that the South African sugar industry generates an annual estimated average direct income of over US$1 billion, and contributed about 0.3% of South Africa's GDP in 2016, based on revenue generated through sugar sales in the SACU region as well as world market exports. The industry makes an important contribution to employment and sustainable socioeconomic development, particularly in rural areas. This is built on its agricultural and industrial investments, foreign exchange earnings, labor intensity, and linkages with major suppliers, support industries, and customers. It is a diverse industry, combining the agricultural activities of sugarcane cultivation with the manufacture of raw and refined sugar, syrups, and specialized sugar by-products and coproducts (Petersen et al. 2017). The sugar industry has the potential to be a producer of renewable energy, biofuels, and bioplastics (Farzad et al. 2017b; Mandegari et al. 2017a, b).

An important feature of the sugar industry is employment in rural and deep rural areas in job-starved regions, where there are often few economic opportunities. Direct employment occurs both in the sugarcane field and the sugar mills and ranges across a diverse array of skills from the farm laborer to agricultural scientist. The sheer size of economic activity generated in rural areas through the activities of sugarcane cultivation and sugar production also generates a vast number of jobs in support industries and commerce. In most cases the sugar mill and accompanying cane farms form the backbone of the nearest rural town and are major contributors to the development of secondary economic activities, and services and infrastructure that otherwise would be absent. A unique relationship exists between sugarcane and sugar production, as cane is a bulky, non-tradable commodity which requires rapid postharvest processing in order to preserve the sucrose in the cane stalk. As a result, sugar mills are always located as close as possible to the cane-supplying zones. The financial viability of these significant capital investments is entirely dependent on a sustainable supply of sugarcane in each mill supply area.

The sugar industry creates approximately 79,000 direct jobs, which represents over 11% of the total agricultural workforce in South Africa. Additionally, registered cane growers supplying cane to the sugar mills also earn from this sector. Indirect employment is estimated to be 350,000 jobs (SASA 2017). Approximately one million people or 2% of South Africa's population depend on the sugar industry for a living (Alimandegari et al. 2017).

15.2.3 Bioenergy Production from Sugarcane in South Africa

Historically, agriculture has been recognized as being an engine for economic growth that can have a strong impact on poverty and hunger reduction. Bioenergy could be an option for stimulating agricultural sector growth, leading to further socioeconomic development and poverty alleviation around the industry, especially through smallholder farmers (Maltsoglou et al. 2013). Sugarcane is increasingly targeted for bioenergy production (Peng et al. 2014). The most important biofuel to date is bioethanol produced from sugars—sucrose and molasses (Petersen et al. 2017).

A bioenergy crop should optimally be high yielding, and fast growing. Moreover, its processing requirements should be low and it should need relatively small energy inputs for its growth and harvest. Sugarcane is the most efficient bioenergy crop of tropical and subtropical regions, and biotechnological tools for the improvement of this crop are advancing rapidly (Waclawovsky et al. 2010). With developments in sugarcane harvesting and cogeneration technology, bagasse and sugarcane trash have become important sources of bioenergy in some countries such as Brazil. Second-generation bioethanol is also being targeted for studies to allow the use of the cell wall (lignocellulose) as a source of carbon for energy production (Alimandegari et al. 2017).

15.2.4 Existing and New Facilities (Case Studies) for Industrial Biofuel Production

South Africa has traditionally been an energy exporter, primarily in the form of coal-derived electricity. However, in recent years, demand has started to outstrip supply and alternative cleaner energy sources are needed (Aghbashlo et al. 2018).

South Africa's history of using biofuel dates back to the 1920s when sugar ethanol was blended with petrol (Blanchard et al. 2011; Pradhan and Mbohwa 2014). The blending was halted in the early 1960s due to cheaper imported fossil fuels, which made blending economically unviable. In 2007, South Africa tried to revive biofuels by developing the Biofuels Industrial Strategy. The strategy proposed adoption of a 5-year pilot program to achieve a 2% penetration level (previously the target was 4.5%) of biofuels in the national liquid fuel supply, equivalent to 400 million liters per annum (van Zyl et al. 2011). The proposed crops were sugarcane and sugar beet for bioethanol, while maize was excluded on the basis of food security concerns. Former homeland areas were proposed for such cultivation and an estimated 1.4% of arable land was implied to achieve a 2% penetration (Maltsoglou et al. 2013). However, this strategy has not been implemented because of changing global petroleum prices and a plethora of non-technological constrictions that hindered biofuel adoption and development. Even some existing molasses to ethanol facilities (e.g., Komati Sugar Mill) have not been operational due to economic unviability (Smith et al. 2016).

Production of ethanol to anhydrous (E10) specification is expensive and will not be feasible without some form of government subsidy or financial incentives. It may, however, be feasible to produce ethanol at 95% purity (suitable for E95 blending), but this will require a parallel distribution network for liquid fuel, or conversion of a dedicated fleet to E95 specification (Hugo 2016). Therefore, there are currently no existing operational or new facilities in South Africa for commercial ethanol production for biofuel applications. Existing ethanol production is utilized to serve markets for potable or beverage-grade ethanol, as well as export markets for green chemicals. Future economic conditions may favor opportunities to utilize the fiber component of cane, in particular for renewable electricity production (Peng et al. 2014). Limited capacity for electricity cogeneration do exist at some sugar mills; however, favorable market prices and incentives for renewable energy do not exist to expand its production.

15.2.5 Lignocellulosic Conversion to Electricity and Biofuels

It is estimated that ~2.5 Mt per annum bagasse is produced in South Africa, most of which is currently burnt in inefficient boilers, to provide the steam and electricity to sugar mills. Further, the tops (green leaves) and trash (dry brown leaves) harvesting residues of sugarcane are mostly burnt on-field, with brown leaves alone (50% of harvesting residue) representing another 1.3 Mt per annum of lignocellulosic feedstock (Smithers 2014; Petersen et al. 2017). This biomass has potential to be converted into 1 Mt per annum bioethanol via biochemical processes (Alimandegari et al. 2017), or export up to 420 MW of electricity if converted efficiently into electricity (Petersen et al. 2017). However, harvesting residues are not available for the mentioned utilization due to current practices of burning cane before harvest. Although, adoption of "green" harvesting will make some of the residue available, it may have a significant negative impact on rural livelihoods as some of the green cane harvesting is likely to be automated. Furthermore, sugarcane bagasse is currently used for low-efficiency energy generation. Therefore, to liberate bagasse for additional energy generation (for biofuel production), capital investment in new boiler-turbine technology will be required (Dogbe et al. 2018).

15.2.6 Challenges and Future Perspectives

Biofuels have a potential to extend and diversify South Africa's energy supply, thus reducing dependence on imported fuels and pollution levels. Developing biofuels is a big challenge to the government of South Africa due to issues related to food security, commodity prices, economic and social concerns, and impacts of land use changes on the environment (Rosen 2018). The production cost of feedstock and employment creation opportunities from agricultural production play a vital role in selecting suitable feedstock for the region. Therefore, further research is required to address these concerns.

The potential of biofuels to fulfill energy and economic security has renewed the public and political interest on biofuels. The government of South Africa established the Biofuels Industrial Strategy in 2007 to address the renewed interest on the need for biofuels in the country, while a successful program to introduce renewable electricity to the national grid has largely excluded the sugarcane industry. Despite several biofuel policies and mandates, biofuel development in South Africa has stalled in the legislative process, and no large-scale commercial biofuel project has materialized yet (Pradhan and Mbohwa 2014). Since considerable investment and infrastructure will be required for continuous supply of feedstock and efficient biomass conversion technologies, rigorous research and comprehensive studies are being carried out to identify feedstock and technologies best suited for the successful establishment of biofuel industry in South Africa. In Table 15.1 some of the recent techno-economic studies on the sugarcane biorefineries for biofuel, biochemical, and biopolymers in South Africa are given.

On the other hand, South Africa stands as the largest sugarcane producer in the African continent. Approximately 3–7 tons of molasses can be produced from 100 tons of fresh sugarcane. Therefore, it is estimated that about 1 Mt per annum molasses is being produced as by-product of the processing in the South African sugar factories. There is a potential of 0.3 Mt per annum bioethanol production via sucrose fermentation of molasses. All of the molasses produced by the industry is presently utilized in either (potable/beverage grade) ethanol production or used for livestock feeding.

Table 15.1 Some of the recent techno-economic studies on the sugarcane biorefineries in South Africa

Feedstock(s)	Product(s)	Yield (weight % fuel/feedstock)	Reference
Bagasse and trash	EtOH	26.0%	Alimandegari et al. (2017)
Bagasse and trash	Butanol	11.8%	Farzad et al. (2017b)
Cane juice, bagasse, and trash	Jet fuel	10%[a]	Diederichs et al. (2016)
Bagasse and trash	MeOH/FT syncrude	25.8–29.4%/8.4–12.2%	Petersen et al. (2015)
Bagasse	Pyrolysis products	19.2–30%	Nsaful et al. (2013)
Bagasse and trash	EtOH/butadiene	21.8–33.5%/7.0–8.8%	Farzad et al. (2017a)
Bagasse and trash	EtOH/lactic acid	33.5%/49.3%	Aghbashlo et al. (2018)
Cane juice, bagasse, and trash	EtOH/electricity	5.03–21.8%	Petersen et al. (2017)
Bagasse and trash	Gasification products	20–70%	Farzad et al. (2016)
Bagasse and trash	Butanol	5.6–10.5%	Haigh et al. (2018)

[a]Yield for cane juice to jet fuel: 48%

15.2.7 Concluding Remarks

The South African sugarcane industry has long pursued the options of biofuels and renewable electricity production, as a means to expand its revenue streams and ensure future sustainability of the industry. However, these efforts have not managed to secure sufficient market opportunities to warrant substantial commercial expansions in the production of either, primarily due to the requirement for substantial financial incentives from the government to ensure viability of these investments.

15.3 Guatemala

15.3.1 The Sugarcane Crop in Guatemala

Sugarcane is produced on the far-eastern and Pacific coasts of Guatemala, with the majority of production taking place on the latter. The current national production of sugarcane in Guatemala is about 28.1 million tons per annum, harvested on an area of 270,000 hectares (Tay 2017). Guatemala's agricultural land is the most productive in the world for its yield of sugarcane (Souza et al. 2018), with the current active area of 270,000 hectares has a productivity of 104 tons of sugarcane per hectare. The agricultural land productivity has drastically improved over time due to continuous improvement and research, as the agricultural area and productivity had been 100,000 hectares and 66 tons per hectare, respectively, 30 years ago (Tay 2017).

15.3.2 Sugar Industry: Sugar and Ethanol Production

There are 14 sugar mills operating in Guatemala, 13 of them being on the Pacific zone and the remaining on the eastern region (Tay 2017; Tomei 2015). With the sugarcane production rate of 28.1 million tons per annum and a milling season of 6 months, the average daily crushing rate is 12,000 tons per day, with the Pantaleon mill being the largest at 29,000 tons per day (Pantaleon 2018).

The primary product of the mills is raw sugar, and the total production on an annual basis is about 2.8 million tons (Cairns Group 2016; Tay 2017). The mills are regarded as being highly efficient, with a sugar production rate of about 100 kg per ton of cane, which represents a recovery of about 74% of the initial sugar content of the cane toward sugar. This recovery used to be about 85% around 2009, but has dropped as the steer toward ethanol production from sugarcane had increased. Of the 14 mills, 5 of them cogenerate ethanol from molasses for a combined annual production of 269 million liters (CentralAmericaData.com 2014; Tay 2017), which is mostly exported to Europe. The production of ethanol has been rapidly expanding due to the increased demand by the European Union for biofuels, as production had increased by 33% since 2011, which is equivalent to an average annual expansion of 4.8% (Tay 2011).

15.3.3 Cogeneration of Electricity

The sugar mills in Guatemala generate electricity all the year-round, instead of only during the harvesting season when bagasse is available. This is achieved by the use of high-efficient flexi-fuel boilers that utilize bagasse during harvest and fossil fuel (such as bunker fuel) during the growing season (Johnson and Seebaluck 2013). The combined installed capacity of the mills is about 574 MW (Tay 2017) during the harvesting season, which is normally reduced by about 32% (Johnson and Seebaluck 2013) during the growth season when fossil fuel is used. The expansion of the electricity generation has also been quite rapid, as it expanded by about 85% since 2011 (Tay 2011), which is equivalent to an annual average expansion of about 10.8%. This increase is a combination of two factors, i.e., the increase in sugarcane throughput and installment of more efficient energy generation equipment.

15.3.4 Challenges and Future Perspectives

From a technical and economic viewpoint, not much can be said about any direct challenges regarding the expansion of sugarcane bioenergy and bioethanol industry in Guatemala, as the growth of either product has been expanding rapidly through the last decade(s). There is, however, little potential land left for continued expansion of the sugarcane crop (Tay 2017). Thus, if Guatemala is to expand its capacity for ethanol production, the remaining sugar-only mills will require annexed distilleries for ethanol production from molasses, or the conversion of lignocelluloses to ethanol.

The challenges in Guatemala's biofuel production lie predominantly in the socio-environmental sphere, which range in issues pertaining to land access of the general population, labor practices, and water pollution (Tomei 2015). Most of the land in Guatemala is owned by "elite" families and generally the farmers rent land from these elites for their own livelihoods, which for many Guatemalans means micro-farming for self-sustenance and small-scale commercial activities. As the interests in sugarcane farming for biofuels increased due to the economic lucrativeness in the Guatemalan context, land accessibility for such activities by the general population decreased (Tomei 2015). There is also a general lack of labor unions to enforce fair labor practices on the harvesting fields and in the mills, due to the intimidation that labor union members face. Furthermore, the industry reduced the efficacy that labor unions may have, by favoring the use of casual workers over permanent employees (Tomei 2015).

Poor water quality is a major concern for the public health in Guatemala, and the sugarcane industry is one of the major contributors to the pollution of natural water resources. This arises mostly because of the wash-off of fertilizers and herbicides from the sugarcane fields, and untreated effluents from the mills (Conley et al. 2010). Furthermore, the sugarcane production and processing industries are one of the major users of freshwater in the country, limiting its access to the underprivileged population (Conley et al. 2010).

15.3.5 Concluding Remarks

Guatemala is one of the top sugar exporters in the world; however, it is not likely that sugar production would increase in the country since the land availability for sugarcane agriculture is saturated. The steer toward bioethanol production for exports to the EU could further decrease the sugar production as it competes for the same raw material. From technical and economic perspectives, the sugarcane industry in Guatemala thrives, given its high capacity of sugarcane agriculture, the balanced production of sugar and ethanol, and the efficient cogeneration of electricity from sugarcane residues that contributes to the national grid.

Both ethanol and electricity production has been expanding rapidly over the last few decades, given the need for greenhouse gas reduction by the use of bioenergy. Legislative policies and their enforcement by the state, however, are urgently needed to mitigate the socio-environmental consequences caused by the rapid expansion of sugarcane operations. These are needed to ensure fair land access for the largely impoverished Guatemalan population, fair labor practices on the sugarcane fields and in the milling operations, and to abate the pollution of the country's water resources by the sugarcane industry. Failure to implement such reforms could cause the perceiving of Guatemalan biofuel as a product of exploitation, negatively affecting its reception by the EU member states.

15.4 Cuba

15.4.1 The Sugarcane Crop

Historically, Cuba has been one of the world's leading sugarcane producers as, prior to 1990, Cuba processed 82 million tons of sugarcane per annum (Alonso-pippo et al. 2008). Then, due to poor policies, unrealistic targets, geopolitical changes (Alonso-pippo et al. 2008), degrading infrastructure, and natural disasters, Cuba's sugarcane production dropped to 12 million tons per annum by 2006 (Pollitt 2010). In the 1970s, national targets to produce ten million tons of sugar had been set by the Cuban government against the advice from experts in agriculture (Alonso-pippo et al. 2008). This led to mismanagement and inefficient practices on the entire production chain of sugar, which in turn led to very high production costs (Alonso-pippo et al. 2008; Patiño 2009; Pollitt 2010).

The high production costs did not bear any consequences to the Cuban government while under Soviet patronage (Alonso-pippo et al. 2008; Patiño 2009), as such patronage assured that Cuba would receive 4 tons of oil per ton of cane it exported (Alonso-pippo et al. 2008). However, with the dissolution of the Soviet Union in the early 1990s, this patronage ended (Alonso-pippo et al. 2008; Patiño 2009; Pollitt 2010). Thus, Cuban sugar was forced into the international markets, where it could not compete economically, and as a consequence, sugar production had to be downscaled as the subsidies required for large-scale production would have crippled the economy (Alonso-pippo et al. 2008; Patiño 2009; Pollitt 2010).

From 2002, the Cuban government instituted a program to revitalize the sugarcane industry by reforming the agricultural and milling practices, in order to reduce the production costs of sugarcane. Thus, production was downscaled even further as the program could only focus on the lucrative harvesting areas with the most efficient mills (Alonso-pippo et al. 2008; Patiño 2009; Council on Hemispheric Affairs [COHA] 2017). The progress of the reformation program, however, met with catastrophe when in 2005, the worse hurricane to have ever struck Cuba in modern history destroyed many of the cane fields (Alonso-pippo et al. 2008; Patiño 2009). The recovery from this disaster has been slow due to lack of resources and required infrastructure improvements which the Cuban government could not afford (Patiño 2009). Between 2005 and 2015, the cane production experienced a minor growth.

15.4.2 Sugar Industry: Sugar and Ethanol Production

The current sugarcane production of 15 million tons per annum (COHA 2017) is about 18% of its historical (highest) production in Cuba. At the moment, there are only 70 mills operating in Cuba, out of the 156 that used to be operational under Soviet patronage (Alonso-pippo et al. 2008; COHA 2017). The mills were originally built in 3 size categories—of which 82 were in the range of <3000 tons per day (crushing capacity); 48 were in the range of 3000–6000 tons per day; and 26 were in the range of >6000 tons per day (Alonso-pippo et al. 2008). Thus, at the current (2016) crushing rate of 15 million tons per annum, the mills have an average crushing rate of about 1300 tons per day, which is far below their intended scales.

The current sugar production in Cuba amounts to no more than the local consumption of 700,000 tons per annum (Alonso-pippo et al. 2008), and Cuba imports sugar to satisfy the local demand. Sugar recovery in Cuban mills is 71%, which is rather low considering that there is currently no competing use such as ethanol production for sugars in the country (Alonso-pippo et al. 2008). Ethanol production from molasses had been practiced at only 16 mills (Alonso-pippo et al. 2008), and the highest annual production on record is about 26 million gallons (COHA 2017). Currently, no ethanol produced in Cuba is used as biofuel for transportation (COHA 2017).

15.4.3 Cogeneration of Electricity

For most of the mills in Cuba, the bagasse generated through cane crushing is burnt in low-efficiency boilers with pressure ratings of 10–20 bars, to provide steam needed to drive the process (Alonso-pippo et al. 2008). Thus, most of the mills are dependent on the grid for the needed electrical energy. For the mills which possess cogeneration capacity, the total production of generated electricity amounts to about 600 MW, of which 5% is exported to the grid (Alonso-pippo et al. 2008).

15.4.4 Challenges and Future Perspectives

The primary challenge facing the Cuban government's plan to rejuvenate the cane fields is the amount of fertilizer required, which cannot be sustained by the current state of its economy. Fertilizer is an import for Cuba, and its purchase was downscaled as the economy shrunk. Also, importing of new or refurbished harvesting equipment that is needed is not affordable to the Cuban economy (Pérez-López 2016). Furthermore, the micro-road infrastructure connecting farms and mills needs to be upgraded to improve the efficiency of cane transportation (COHA 2017).

As noted earlier, the mills themselves are operating far below their intended scales due to the limited supply of sugarcane. It was also noted that the mills have a low sugar extraction rate and that most of the mills are very energy-inefficient in terms of electricity cogeneration. However, it is estimated that replacing the low pressure boilers with high pressure boilers can improve the cogeneration capacity from 600 MW to about 1500 MW (COHA 2017). Ethanol production in Cuba has also been limited because of the government policies, as it was perceived that ethanol production competes with food production (COHA 2017). As there is no evidence of ethanol production in Cuba currently, it is probable that the 16 mills in which ethanol was produced previously have been shut due to the shortage of cane (Alonso-pippo et al. 2008).

The rejuvenation of the sugarcane industry in Cuba requires an inflow of foreign funds through investments into the sugarcane industry (Alonso-pippo et al. 2008; COHA 2017). Such funding is required for the much-needed fertilizer for expanding crop growth, importing harvesting machinery, and upgrading of infrastructure as well as sugar mills. Further investments will also contribute toward improving the efficiency of the mill operations and augmenting the cogeneration capacity (Sapp 2014).

15.4.5 Concluding Remarks

The dilapidated state of the Cuban sugar industry clearly demonstrates the adverse consequences of disregarding established agricultural and industrial practices and the overdependence of an industry's success on a certain geopolitical situation. The trade agreements between Cuba and the Soviet Union had formed the backbone of the Cuban economy, and the lucrativeness of this deal on the Cuban end had caused complacency as far as industrial and agricultural practices in the sugar were concerned. As soon as the geopolitical situation altered, the sugar industry became unsustainable.

The Cuban economy and the sugarcane industry are effectively caught in a vicious circle, as the Cuban economy's dependence on its sugarcane industry had crippled it, while on the other hand, the imports of the necessities to revive the sugar industry is not affordable to the Cuban economy. Thus, the only means of reviving the economy is to allow foreign investment directly into the sugarcane industry to provide the funding for importing of the capital and consumables needed to boost sugarcane production and improve the current state of technology. A sugarcane industry that is in a poor technological state cannot make any meaningful contribution to bioenergy, as the mills should have an acceptable operating efficiency before bioelectricity can be exported to the grid. Furthermore, the current governmental policies in Cuba toward ethanol production for use as transportation biofuels should be reconsidered.

15.5 Argentina

15.5.1 The Sugarcane Crop

The sugarcane fields are primarily located in the northwestern regions of Argentina, and the total production of the country was 25 million tons in 2016. Sugarcane is used for both raw sugar and ethanol production in Argentina (Joseph 2016). In the last 10 years, there has been no significant increase in the amount of cane grown, as there had only been a total increase of about 11% (Joseph 2011). However, since 2010, the amount of cane used directly for ethanol production has increased from about 2% in 2010 to about 23% in 2016 (Joseph 2011, 2017).

15.5.2 Sugar Industry: Sugar and Ethanol Production

There are 20 large sugar mills built in Argentina, with 15 being in the Tucuman region and 5 in the Salta region (Joseph 2011), Out of these mills, 9 mills currently coproduce ethanol (Joseph 2017). With a 6-month harvesting period from May to November (Braier and Marenco 2018), the average crushing rate is about 7000 tons cane per day for each mill, with the smallest mills operating at 1000 tons cane per day and the larger mills operating at 10,000s tons cane per day (The Sugar Engineers 2018).

The annual sugar production by the end of 2016 harvesting season was 2.1 million tons (Joseph 2016). This is a considerable reduction of about 13% from the 2009 harvest (Joseph 2010), due to increasing crop usage for ethanol production. Ethanol was traditionally only produced from molasses, but has increasingly been produced directly from sugarcane juice, as it has been offering better returns to the milling operations (Joseph 2017). The ethanol produced from sugarcane amounts to about 525 million liters per annum, and contributes about 46% to the total ethanol produced in Argentina (Joseph 2017). In addition to the 525 million liters produced for fuel, a further 80 million liters is produced for nonfuel applications, such as pharmaceuticals and beverages (Joseph 2017). Since 2011, the total ethanol production has increased by a factor of about 8, which was mainly achieved by using cane juice directly for ethanol production (Joseph 2017).

15.5.3 Cogeneration of Electricity

Most of the mills in Argentina burn bagasse as a means of disposal in low-pressure boilers with back pressure turbines to provide the steam and electricity needs of the plant. However, four mills generate electricity efficiently enough to sell a surplus to the grid (Mele et al. 2013a, b). While it was not possible to obtain an exact value for the total installed capacity for electricity generated from bagasse, it is estimated that the proportion of total available bagasse in Argentina that is transformed for electricity generation amounts to only 19% (UN Data 2018). Thus, the potential to increase the capacity of electricity production by the sugarcane industry by at least fourfold exists predominantly in upgrading the mills' equipment to improve energy efficiency.

15.5.4 Challenges and Future Perspectives

As a member of the Paris Agreement on Climate Change and an attendee of COP-22, Argentina is committed to reducing its greenhouse gas emissions by 18% unconditionally by 2030, and 30% conditionally by the same year (Joseph 2017). Two possible manners through which this target may be achieved is by (1) implementing the share of 20% renewable electricity mix before 2025 and (2) instigating high biofuel blends of ~25% or greater (Joseph 2017). For achieving either target, the sugarcane industry plays a pivotal role as a large-scale producer of biofuels and bioelectricity, and the Argentinian government incentivizes ethanol production and bioelectricity generation through tax cuts and premiums (Global Data 2017; Joseph 2017).

As the mills in Argentina can generally be regarded as inefficient, the challenges facing the sugarcane industry lie predominantly in the upgrading of sugar mills in terms of their energy consumption vs. efficiency of the cogeneration energy circuit. Thus, it is expected that a number of projects aimed to improve the installed electricity generation capacity of the sugarcane industry will commence in order to meet the target for the share of renewable electricity in the national Argentinian electricity grid. One such project is already in progress, as the La Florida mill is currently in the process of installing a 45 MW cogeneration plant (Sugaronline.com 2018). These projects, however, are very capital intensive and might require foreign investments to provide funds.

In order to meet the short-term increased blending target from 10% to 12% that was mandated in 2016, three sugar mills are in the process of being upgraded to produce an extra 150,000–200,000 liters of ethanol per day (Joseph 2017). As higher blending ratios such as 85% ethanol are mandated in the long run, it is likely that the remaining sugar-only mills will install distilleries, and that more sugarcane will be used directly in ethanol production. However, this will also mean that vehicles in Argentina will require flex-fuel engines (Joseph 2017).

15.5.5 Concluding Remarks

The sugarcane industry in Argentina contributes considerably to the country's commitments to reduce greenhouse gas emissions by a significant extent through biofuel production and insignificantly through bioelectricity production. To increase the production of ethanol, for fulfilling the demand created by mandating of higher blending ratios of biofuel to fossil fuel, more of the existing mills will require annexed distilleries that convert molasses into ethanol. Else, increasing ethanol production by increasing the direct use of sugarcane juice for ethanol will reduce the sugar production. With regard to bioelectricity generation, and its contribution by the sugar mills of Argentina toward the clean energy targets, investments are required to revamp the technological status of the mills, by installing high-efficiency cogeneration equipment.

15.6 Vietnam

15.6.1 Status of Sugarcane Crop in the Country

Sugarcane is an important industrial cash crop in Vietnam. It was introduced in the southern areas of the country in the early twentieth century. Later, it was planted in the central and Mekong river delta regions (Vietbid 2001). Thus, the area planted with sugarcane has been increasing over the years. According to Vietnam Sugar Association, the current sugarcane plantation occupies an estimated area of 305,000 hectares (Hieu 2016). Some large-scale farms, ranging from 10 to 15 hectares of land, also cultivate sugarcane. The crop is a source of employment and income to more than 337,000 sugarcane-growing families (Nguyen 2017).

Vietnam's average cane yield in 2017 was 64.4 tons per hectare with 10% sugar content (Nguyen 2017; Toan et al. 2016). Despite significant improvement in the crop productivity, sugarcane faces many challenges including climate change, extended drought, outdated varieties, and slow adaptation of new technology in the country. Thus, the Vietnam government is working on improving the quality of both cane yields and sucrose, with significant research efforts to develop varieties with early maturity, high sugarcane yield, and increased sucrose content (Toan et al. 2016).

Figure 15.2 depicts annual production of sugarcane from 2005 to 2015. Although the plantation area increased from 266,331 to 301,900 ha between the period, the crop production has not improved. The production was low for the 3 consecutive years (2008–2010) due to severe droughts (Toan et al. 2016). The production started to increase again from 2011 and reached the highest of 19.82 million tons in 2013. The production for 2015 was also slightly low compared to that of 2014 due to decrease in plantation area (284,500 ha) (Trinh and Linh Le 2018).

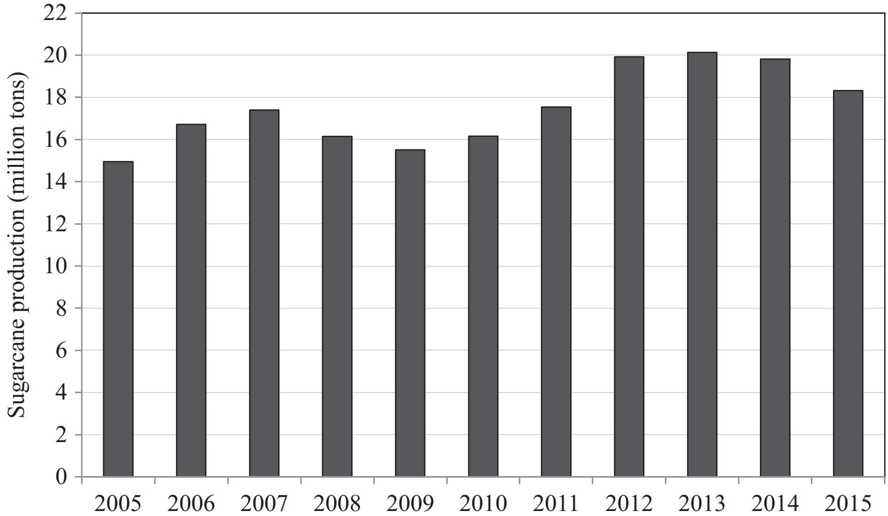

Fig. 15.2 Production of sugarcane in Vietnam from 2005 to 2015. (STATISTA 2018)

15.6.2 Sugarcane Industry: Sugar and Ethanol Production

Sugarcane is the second largest crop for bioethanol production after cassava in Vietnam. Bioethanol production at large scale uses molasses from sugar mills as a raw material. Currently, there is only one factory that uses a combination of cassava and molasses to produce ethanol. However, the contribution of ethanol from molasses is very small (3–6%) (Trinh and Linh Le 2018). About 100 million tons of ethanol is produced annually in Vietnam. Molasses normally contains approximately 40 and 45% sugar (Hieu 2016). Vietnam has 41 sugar mills which can generate around 3.6 million tons of sugarcane molasses annually (Van Loc 2016). The molasses produced from these mills can be used to engender up to 912 million liters of bioethanol.

Moreover, the government of Vietnam is encouraging policies to support development of biofuels since 2003 (Asian Biomass 2013). In 2007, the National Energy Development Strategy to 2020, with vision to 2050, was developed to boost the development of new renewable energy to replace the use of fossil fuels. To achieve this goal, short-, medium-, and long-term strategies were formed, including (1) improving research and development, (2) establishing strong industry that utilizes agriculture products to produce biofuels, (3) developing policies and framework that will attract investors (local and foreign) to establish vibrant biofuel industries, and (4) promoting international cooperation to facilitate the biofuel sector (Trinh and Linh Le 2018). In this regard, government provided tax incentives for importation of new equipment for the local and international companies, and the companies were also given land for the period of 20 years.

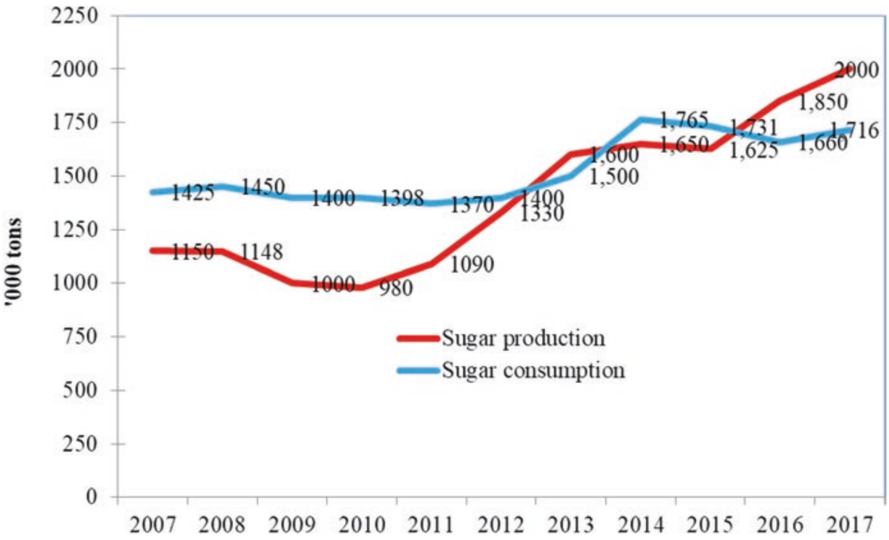

Fig. 15.3 Sugar production and consumption in Vietnam from 2007 to 2017. (USDA 2017)

In terms of sugar production, Vietnam has 41 sugar mills with total milling capacity of 139,800 tons of sugarcane (Nguyen 2017). About 70% of sugarcane is processed by small cottage industries, having limited capacity of less than 100 tons cane crushing per day. The remaining 30% is processed by commercial cane mills. The small-scale processing mills are located in the key areas where they can be easily accessed by the local growers. Nevertheless, the mills are highly inefficient due to high loss of sucrose and production of sugar with poor quality. Alternatively, farmers can transport the sugarcane to bigger commercial-scale mills, but the route is difficult and expensive.

The annual sugar production of the country in 2017 was 2.0 million tons (United States Department of Agriculture [USDA] 2017). The trend of sugar production and consumption in the country for the period of 10 years (2007–2017) is shown in Fig. 15.3. Sugar production has increased by 74% from 1.15 million tons in the last 10 years. However, sugar production for years 2009, 2010, and 2011 was less due to low sugarcane production (Fig. 15.2) caused by prolonged drought. Yet, in general, sugar production has increased more rapidly than the consumption during the past 10 years.

15.6.3 Challenges and Future Perspectives

The biofuel program in Vietnam remains important for its strategy of reducing CO_2 emissions in transportation sector. However, the implementation of this program has been facing various challenges including low social acceptance and shutdown of biofuel plants due to low local demand. Since 2015, three biofuel factories have closed due to lack of local market. Similarly, the biofuel industry is facing technological barriers because most of the factory uses old technology compared to the foreign countries. Thus, biofuel plants are not cost competitive due to high energy demand. Moreover, availability of human resources is also a challenge as the biofuel industry requires skilled labor and experts to drive scientific research and development activities.

In order to increase biofuel uptake in the country, the government should mandate the blending program. Such blending program will lead to expansion of the sugarcane production and processing contributing toward Vietnam's mission to increase employment and enhance income for the rural communities. The government indicates that an additional 450,000 hectares are potentially available for sugarcane production (Van Loc 2016). Based on the current sugarcane yield of 64.4 tons cane per hectare, there will be additional 28.98 million tons of sugarcane available for processing to sugar or bioethanol. The expansion of sugarcane plantation is also expected to generate huge amounts of bagasse for ethanol engenderment and electricity cogeneration (Zwebe 2012).

15.6.4 Concluding Remarks

Despite present-day challenges, Vietnam remains optimistic about the potential to expand both sugarcane cultivation and bioethanol production, which will require substantial new investments into the industry, in both existing and new sugar mills. The associated increase in economic activities is likely to bring socioeconomic development to the rural communities where these industries are located, or launched.

15.7 Philippines

15.7.1 Status of Sugarcane Production in the Country

Sugarcane is one of the major crops in the Philippines. It is cultivated in 20 provinces across the country. The crop is grown in more than 62,000 farms occupying an estimated area around 420,000 hectares, which is 7.43% of arable land (Bautista-Martin 2012). The majority of the farms (81%) are operated by small-scale holder farmers (0.01–5.00 hectares) (Anon 2016). One hectare of sugarcane usually requires 15 workers. This means that the labor force directly employed by the industry, including sugar mills and refinery, is around 700,000 with the additional five million indirectly dependent on sugar production for livelihood.

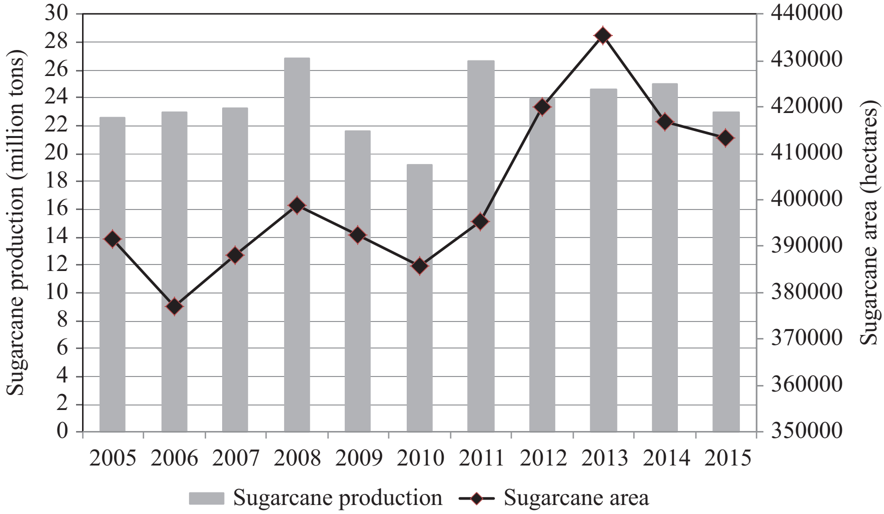

Fig. 15.4 Sugarcane production and sugarcane area from 2005 to 2015. (Bautista-Martin 2012; STATISTA 2017)

Figure 15.4 shows the trend of sugarcane production and the area cultivated for the period of 10 years (STATISTA 2017). The average annual production is around 23.6 million tons. The lowest crop production was observed in year 2010 (19.2 million tons) when the country experienced El Niño drought. On the other hand, the highest production was observed in 2008 (26.9 million tons). Generally, the increase of farming area did not improve crop production in many instances. This could be attributed to inadequate investments and climate change in recent years (Shrivastava et al. 2011). The latter is expected to continue hampering any increase in sugarcane production. In an attempt to facilitate sugarcane production, the Sugarcane Industry Development Act (RA 10659) was signed into law in March 2015 in response to inadequate sugarcane production and inefficient milling operations. The Act provided US$43 million for infrastructure support program, research and development, socialized credit, grants to block farmers, and scholarship grants (Corpuz 2017).

15.7.2 Sugarcane Industry: Sugar and Ethanol Production

The sugar industry in the Philippines is a multiproduct industry with sugar, bioethanol, and power as its major products. The country has 29 sugar mills with an average milling capacity of 185,000 tons cane per day (Corpuz 2017). The country also has 14 operating sugar refineries with total refining capacity of 8800 tons per day (Anon 2016).

In terms of sugar production, the production has been 2.4 million tons for the last 10 years (USDA 2017). Most of the sugar produced is for the local market. However,

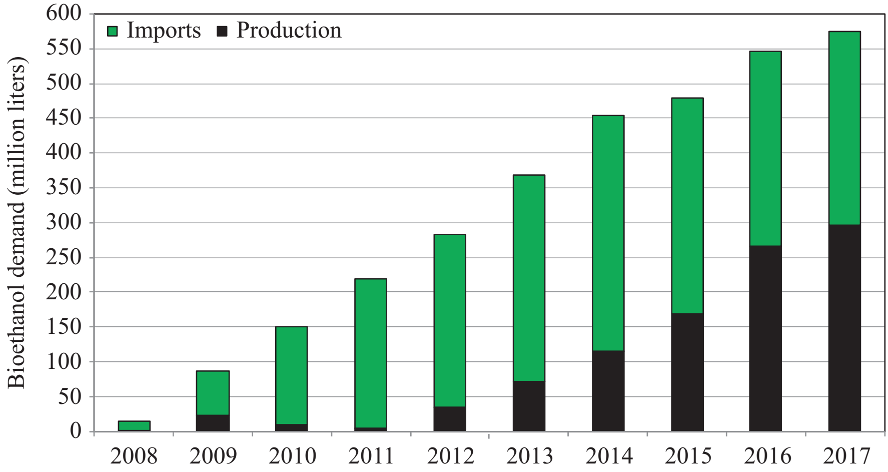

Fig. 15.5 Production and importation trend of bioethanol from 2008 to 2017. (Corpuz 2017)

the country also set aside about 200,000 tons for export to the United States, which is considered as a favorable market. Generally, the industry produces sufficient amount to meet the domestic demand. Consequently, any expansion in the industry is meant for bioethanol production. Nevertheless, sometimes El Niño brings extended drought damaging the crop resulting in poor yields.

The history of bioethanol production in the Philippines can be traced back to 2006 when the Bioethanol Act opened the gates to new investments in the sugarcane industry through bioethanol production facilities. In 2007, voluntary 5% bioethanol blend in petrol was implemented and the ethanol employed for the purpose was imported from abroad (Corpuz 2017). The first biorefinery with a capacity to produce 30 million liters of bioethanol annually was opened in 2009 by San Carlos Bioenergy. The number of bioethanol plants had reached 11 by 2017, with a total capacity of 322 million liters.

Figure 15.5 depicts the production and importation trends of bioethanol for the past 10 years (2008–2017). The production shows exponential growth from 0.364 million liters in 2008 to 296 million liters in 2017. The observed growth is driven by the Biofuels Act. The said law mandated oil companies to blend bioethanol with petrol at 5%. Currently, the fuels distributed by companies in the community are blended with 10% bioethanol. The blending ratio will be increased to 20% by 2020, with an ultimate target to achieve a blending of 85%, according to the National Renewable Energy Program.

Nevertheless, the local demand is considerably higher than the production. The current local production can only supply around 52% of the demand, and the remaining portion has to be imported. The United States is a leading exporter of ethanol to the Philippines. In 2015, the country spent over $170 million to buy ethanol from the United States. Overall, bioethanol imports, however, declined by

10.6% to 261 million liters from 311 million liters in 2015 due to increase in local bioethanol production.

15.7.3 Challenges and Future Prospects

The sugar industry of the Philippines faces various challenges including sugar tariff variation, poor performance of sugar mills, profitability uncertainty, and implementation of biofuel and renewable energy laws. The country has also been facing prolonged drought in recent years, hence affecting the sugar industry. The research and development efforts are being carried out to develop new varieties of sugarcane with intrinsic properties of early maturity, high yield, and improved sugar content. The research also explores the possibility of using the bagasse as a feedstock for second-generation ethanol production. According to the bioethanol Act, the production of second-generation ethanol at commercial scale is expected to be realized by 2030.

The implementation of biofuel law has created a sustainable market for locally produced bioethanol. However, the current capacity cannot supply the demand. To address the gap, the fuel companies import their additional requirements from other countries preferably the United States and Brazil. Notably, significant efforts have been employed to increase the sugarcane production during the last 10 years. The area under the sugarcane plantation has increased from 391,552 hectares in 2005 to 413,264 hectares in 2015. However, these efforts do not reflect expected increase in sugarcane production (22.6–22.9 million tons). Furthermore, the current ethanol production process uses sugar molasses as the raw material (first-generation). The second-generation ethanol (ethanol from bagasse) needs to be integrated along with the first-generation production. The integration of second generation will add up to 40% of the ethanol produced from first-generation technology (Benjamin et al. 2014).

15.7.4 Concluding Remarks

The large local market for sugarcane-derived products, including bioethanol, is likely to continue driving the expansion of this industry in the Philippines. The booming of the industry was made possible by the biofuel law which mandate blending of ethanol with gasoline. The ultimate goal of the blending program is to reach 85% ethanol. There may also be potential to increase imports from nearby countries, to avoid the long-distance import of ethanol from the United States and Brazil.

15.8 Sri Lanka

15.8.1 Status of Sugarcane Crop in the Country

Sugarcane makes a significant contribution to the national economy of Sri Lanka by reducing the cost of sugar import. In 2012, the country spent a total $385 million on importing sugar (Kodituwakku 2013). Sugarcane is also a source of employment and income for the majority of people living along the farming areas and the sugar mills. Nevertheless, sugarcane yields per hectare have declined from its maximum of 66.9 tons to an average of 44.1 tons over the last 8 years (Fig. 15.6) (FAOSTAT 2017). The maximum yield of Sri Lanka has been lower than the average yields of other Asian countries such as India (67.3 tons per hectare) and Thailand (68.8 tons per hectare) (Keerthipala and Harmawardene 2000; Kodituwakku 2013). The likely reasons for this reduction could be the change of climatic conditions and the change of ownership of land from government to private sector. About 60% of the arable land in Sri Lanka is located in the dry zone (Keerthipala and harmawardene 2000). The sugarcane farms are normally rainfed or operated by irrigation. Low sugarcane yield is expected for the rainfed farms when prolonged drought occurs, consequently reducing the yield, harvested area, and the average sugarcane production per year (Fig. 15.6).

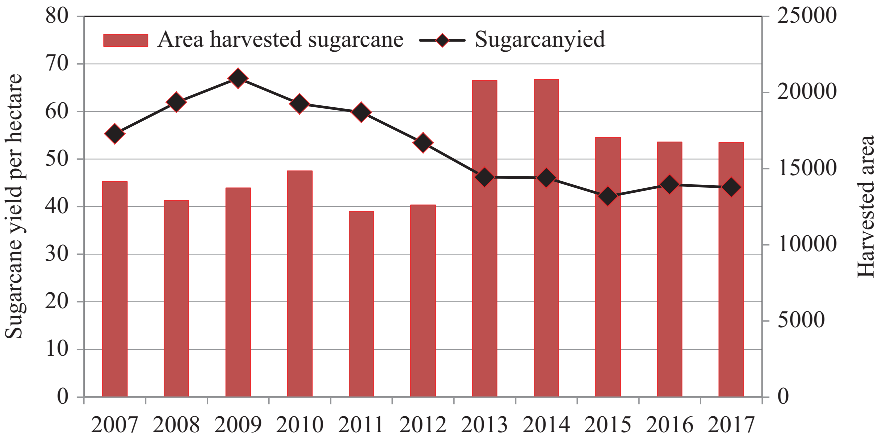

Fig. 15.6 Sugarcane yield per hectare and area harvested for sugarcane in Sri Lanka from 2007 to 2017. (FAOSTAT 2017)

Fig. 15.7 Sugarcane production, import, and consumption in Sri Lanka from 2007 to 2017. (Keerthipal 2016; USDA 2017)

15.8.2 Sugarcane Industry: Sugar and Ethanol Production

Sri Lanka does not currently produce ethanol from sugarcane. However, the country is expecting to use the sugar molasses for bioethanol production in the future. Sugar industry of Sri Lanka is very weak and it is going to take many years before it could be able to produce enough sugar to meet the local demands. Sugar production is growing very slowly for the past 10 years (Fig. 15.7). The present total annual production of sugar is 65,000 tons, which is around 9.8% of the current annual demand of 665,000 tons (USDA 2017). Possible reasons for the slow growth could be due to closure of some of the mills due to civil war, change of management from public to private sector, unattractive policies in the sugar sector, and the variations in sugar prices. The country is lacking a coherent government policy to protect the interests of the stakeholders.

15.8.3 Challenges and Future Perspectives

There are many challenges for the sugar industry in Sri Lanka. The country uses old technologies and machines to manufacture sugar leading to high cost of production. The industry also faces shortage of skilled labor. Furthermore, the research and development has not been sufficient to increase cane production per hectare. Moreover, the country does not use full potential of by-products of the crop after sugar extraction. For example, the sugar mills do not use bagasse to produce electricity even for their own operation; rather the boilers use oil which enhance the cost of production. The cost of production must be lowered for sustainable growth of the sugar industry in Sri Lanka.

According to the Sugar Development Project announced in 2015 (Lanka Business Online 2015), Sri Lanka has planned to increase the area for sugarcane plantation and the number of processing mills from the current 4 to 19 (Keerthipal 2016). The plan aims that 50% of the sugar demand should be produced locally by 2020. This means that the country should produce around 500,000 tons of sugar annually (according to projected sugar requirement of one million tons by 2020). The country will need to cultivate sugarcane on around 113,000 hectares of land (based on the current sugarcane yield of 44.3 ton per hectare). Additional land of around 100,000 ha has been proposed for possible sugarcane expansion in Kurunegala, Budalla, Monaragala, and Hambantota districts. However, unfortunately, these plans have not been realized yet. A complete restructuring of the sugar sector is needed in this regard. All these problems are hindering any bioethanol production in the country. Government policies should also be related to bioethanol production rather than sugarcane production generally.

15.8.4 Concluding Remarks

The substantial local sugar demand, and limited local production, continues to create opportunities to expand both sugarcane and biofuel production in Sri Lanka. These will only be realized through a concerted effort to attract the necessary investment to estimate this potential. However, researches and studies on biofuel production can be commenced to define the most feasible approach for commercial implementation considering country's context.

15.9 Conclusion

In this chapter, the status of sugarcane biofuel production in South Africa, Guatemala, the Philippines, Argentina, Vietnam, Cuba, and Sri Lanka with ~9% of the global sugarcane production has been studied. The effective strategies in the mentioned countries should be placed to use the capacity and expand sugarcane industry, not only to produce more sugar for internal demand and export but also to move toward bioenergy production strategies for sugar industry valorization. Biofuels, particularly ethanol, have been expanding rapidly over the last few decades in some countries such as Brazil, the United States, and several EU states, given the need for greenhouse gas reduction and sustainable development. The road of sugarcane biofuel is being paved by such countries and the successful experiences can be used to expedite expansion of sugarcane biofuels. Legislative policies and their enforcement by the state, however, are also required to mitigate the socio-environmental consequences caused by the expansion of sugarcane industry considering biofuel extension.

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