The Potential of Sugarcane Bioenergy in Fiji

Abstract: Biomass production, utilisation and losses from 1993-2012 were analysed for Fiji. Total theoretical annual average biomass potential was 83PJ. Sugarcane alone has the potential energy of 52PJ annually and 137.64 million litres of ethanol could be produced from sugarcane, cassava and sweet potatoes in a year. Sugarcane (excluding the local sugar consumption) has the potential to produce 129.25 million litres of ethanol which is 29% more than the total motor spirit imported in 2010. Bagasse has the potential to generate 8.2PJ of energy.

Key Words: (biomass, bioethanol; energy, residues, production, Fiji).

1. Introduction

Fiji is a least developed country (LDC) with a land mass of 18,272 km^2 spread over an Exclusive Economic Zone (EEZ) of 1.3 million km^2. Viti Levu is the largest island, which covers 10,390 km^2 followed by Vanua Levu with 5538 km^2. These two islands account for 87 percent of the land area and 90 percent of the population (Woods et al. 2006).

The total land area in Fiji is approximately 1,827,000 ha of which 9.17% is arable, 4.65% is used for perennial crops (Anonymous 2014b). Lands in Fiji are managed through three unique systems – Native land, Crown land and Freehold land. Out of the total land in Fiji, 83% is Native land, 10% is Freehold land and 7% is Crown land (Anonymous 2012). The majority of Native lands are leased to sugar cane farmers on 30 year agricultural leases administered by the iTaukei Lands Trust Board (iLTB). This study found that sugarcane was the major source of biomass energy in terms of food (sugar) and energy as fuels (bagasse).

Bagasse has been used as a primary energy source for many years, however methodologies for assessing the potential of other sources of biomass energy are still emerging in Fiji. Sugar production in Fiji began in 1872 (Anonymous 2009) and since then it has played an important role in the country's economy and has been providing biomass (bagasse) energy for all four sugar mills with surplus electricity production. However, a significant decrease of 44% in sugarcane production occurred between the year 2000-2011 (Figure 1) which has effectively lowered the biomass energy contribution to Fiji's energy supply. Obviously further similar decreases in sugarcane production will threaten the sugarcane bioenergy potential.

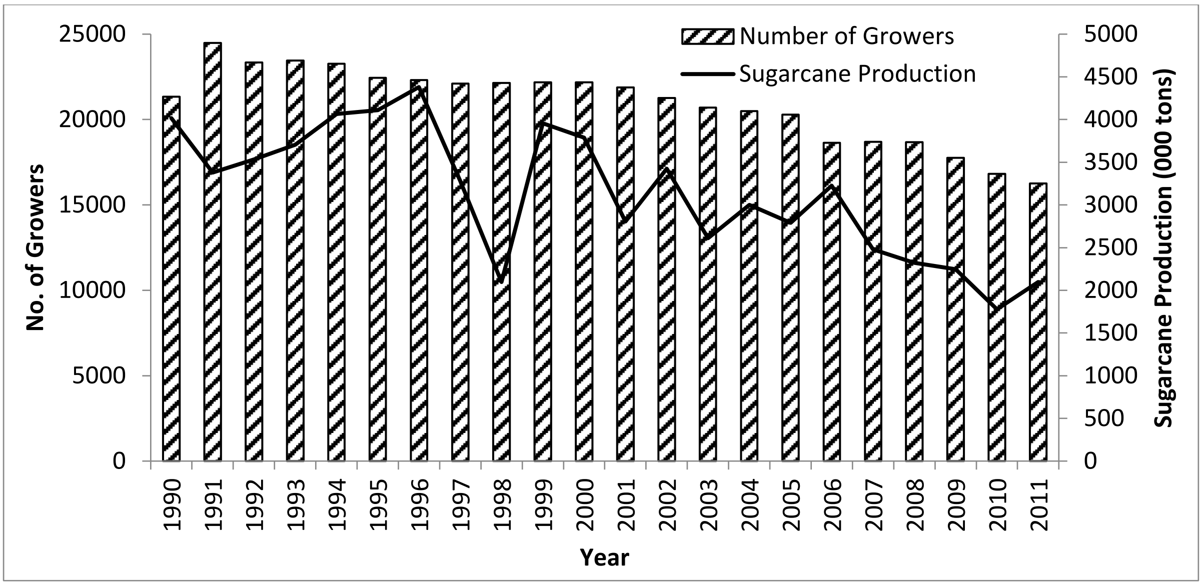


Figure 1: Sugarcane production details for the period of 22 years (Fiji Bureau of Statistics 2012).

The decrease in sugarcane production was mainly due to declines in the number of growers. This is because farmers were evicted from their farms upon expiry of leases and as a result their farms remained either idle or not fully utilised by the incoming farmers. Another factor which contributes to the decline is the increase in farming costs due to increase in labour, transportation and fertilizer prices, resulting in less profit to farmers (Khan 2011). However, even with current production, the sugarcane industry has the potential to lead the renewable energy contribution to Fiji's overall energy balance.

Field survey indicated that the farmers are of the opinion that the current sugarcane payment should be increased to FJ$100/tonne in order to initiate their interest again. However this is not viable in the current sugar production scenario with the European Union sugar quota ending in 2017. A payment of ??US$/tonne could only be possible if the sugar industry strengthens its bioenergy programme and produces ethanol and electricity. Farmers are interested in selling their sugarcane residue (cane tops) to mills for electricity generation.

Currently, hydro energy dominates the renewable energy sector in Fiji. In 2012, 822,804 MWh of electricity was generated (Dean 2012) as shown in Figure 2. Generation constituted 63.6% Hydro, 33% diesel and heavy fuel oil, 1% wind and 2.4% from Independent Power Producers (IPPs) supported from bagasse produced by Fiji Sugar Corporation and wood chips produced by Tropik Wood Industries Limited. In Fiji, energy is consumed by 5 important sectors - transport, commercial, agriculture, industrial and residential. Figure 3 below depicts the proportion of energy consumed by different sectors in Fiji out of total energy (41.7 PJ) produced (Anonymous 2004).

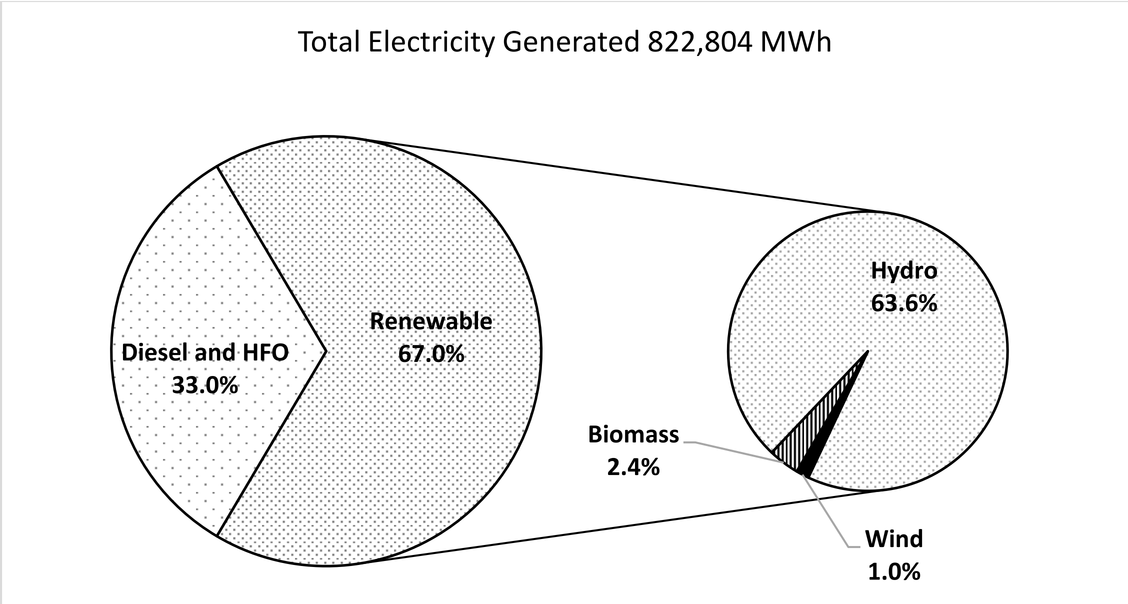


Figure 2: Electricity generated in year 2012 (Dean 2012)

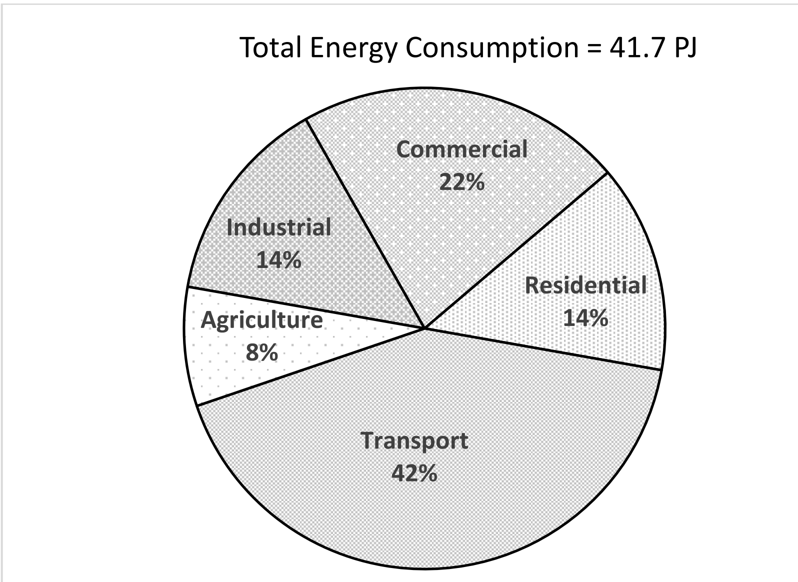


Figure 3: Energy consumption by sector (Nakavulevu 2013)

The total amount of fossil fuels imported in 2010 was 773 million litres from which 101.8 million litres was motor spirit afor transportation and small machine operations. Gas Diesel oil had the highest import among other fuels (391 million litres) as this is also used for power generation apart from agricultural and transportation usage.

Biofuels could play a vital role in Fiji's transport sector via the use of biodiesel (and its blends with diesel for diesel engine vehicles) and via ethanol (and its blends for petrol (gasoline) engine vehicles). Coconut oil (CNO) is the only biofuel currently produced in Fiji. CNO can be used directly in modified diesel engines or blends with petroleum diesel. Ethanol on the other hand can be produced from sugarcane juice, molasses, cassava and sweet potatoes which are readily available in Fiji. However, there are some reservations to the use of cassava and sweet potatoes because of perceived food security issues. The use of molasses does not pose any such threats.

The current fuel standards specify that diesel can contain 5% volume by volume maximum biodiesel (Anonymous 2011) and petrol (gasoline) can contain 10% volume by volume ethanol maximum (Anonymous 2007). Fiji currently does not have any policies for ethanol blending in place. However, it is anticipated that policies will be in place in the near future. Table 1: Annual crop production in Fiji, product energy content and residue energy content

Feedstock	Annual average 10 Yr production yield (Ton/Ha)	Product Energy Content (GJ/Ha)	Residue energy content (GJ/Ha)	Total Energy Content (GJ/Ha)
Cassava	12.79	71.62	67.02	138.64
Sugarcane	45.68	242.11	492.43	734.54
Sweet Potatoes	3.75	20.63	8.25	28.88

Notes: Annual average yield was calculated using data from FAOSTAT for years 2003-2012. Product energy content for crops and residues were obtained from (Hemstock and Hall 1995; Amoo-Gottfried and Hall 1999; Rosillo-Calle et al. 2006a). Total energy content is a sum of Product energy content and Residue energy content.

Table 1 shows that sugarcane has the best prospects for ethanol production in Fiji. The molasses produced, which is currently exported, could contribute to the production of 34 million litres of ethanol from which 25% could be used locally and the rest could be exported for high returns (Nakavulevu 2013).

In order to assess the biomass energy potential in Fiji - including sugarcane bioenergy (ethanol) potential - terrestrial above ground biomass production and usage was analysed for the twenty years from years 1993-2012 using FAOSTAT database and local data. The specific energy values were derived from earlier work (Hemstock and Hall 1995, 1997; Amoo-Gottfried and Hall 1999; Rosillo-Calle et al. 2006b).

Total biomass production, present utilization levels, available theoretical energy and potential available biomass residues from agriculture and forestry were calculated. All biomass energy flows were followed from their production at source, losses at harvest and all processes through to end use. Finally, production categories were clustered into an end use group such as food, fuel and residues.

2. Methodology

Data Source

Data on agricultural production (food), forestry removals and livestock production were obtained from FAOSTAT, 2014 and were used to estimate the total theoretical biomass available. Data on sugarcane, bagasse and molasses were obtained from Bureau of Statistics and Fiji Sugar Corporation and compared with FAOSTAT.

Production data

Potentially recoverable residues from forestry and agricultural land use were estimated using the technique suggested by (Rosillo-Calle et al. 2006b). The 20 year annual average (1993-2012) crop production data were obtained from (FAOSTAT 2014) and were verified with other sources (Khan 2009; Fiji Bureau of Statistics 2012) to provide a broader assessment. Crop residues and by-products for which the data was not available were derived using technical coefficients and conversion factors obtained from various sources (Hemstock and Hall 1995, 1997; Amoo-Gottfried and Hall 1999; Rosillo-Calle et al. 2006b; Jingura and Matengaifa 2008; Okello et al. 2013; Shonhiwa 2013).

The annual dung production was formulated from the livestock population and calculated using coefficients verified from various sources which take into consideration the production of fresh dung per animal, the dry material content and seasonal factors (Amoo-Gottfried and Hall 1999; Rosillo-Calle et al. 2006b; Mohammed et al. 2013). Livestock population data was derived from FAOSTAT.

The agricultural crop and above ground biomass production only were considered by this research - water surfaces were not included in this study. All roundwood volumes were assumed to be solid with the conversion equivalence of $1m^3$ of solid roundwood = 1.3 ton (Hemstock and Hall 1995; Rosillo-Calle et al. 2006b)

Molasses to ethanol conversion was as follows: 1 tonne of molasses (cane) feedstock can produce 250 litres of ethanol, 1 tonne of cassava (fresh root) can produce 180 litres of ethanol, 1 tonne of sugarcane can produce 70 litres of ethanol and 1 tonne of sweet potatoes can produce 150 litres of ethanol (Kishore and Srinivas 2003; Silalertruksa and Gheewala 2010).

The following energy values (GJ/t air dry, 20% moisture content) assume direct combustion: 1 tonne fuelwood = 15 GJ; 1 tonne of stem wood = 15 GJ; 1 tonne forest and tree harvesting residues = 15 GJ; 1 tonne charcoal = 31 GJ and conversion efficiency of fuelwood to charcoal = 15 % by weight (Hemstock and Hall 1995; Rosillo-Calle et al. 2006b). The term “end use” refers to the gross biomass energy devoted to specific use such as food, fuel etc.

3. Results

Annual Average Primary production established on forestry, agriculture and livestock

Agricultural production (annual crop and residues)

Excluding residues, the average annual crop production in Fiji from 1993-2012 was about 3,268,097 tons with a potential energy of 20.14 PJ. Previously, sugarcane, the economic backbone of Fiji, was by far the most dominant crop in Fiji providing approximately 90% (2.95Mt) of the total crop harvest in terms of mass and approximately 77% (15.6 PJ) in terms of energy potential.

The annual average crop residue (1993-2012) theoretically available as a biomass energy resource was 4,924,517 tons (potential energy of 38.65 PJ). Sugarcane was by far the most dominant residue, despite declining production, providing 96% (4.7 Mt) of the total residue harvested by mass and 94% (36.4 PJ) of the total energy potential.

However, comparing annual averages (from1999-2003 and 2008-2012) as presented in Table 2, the production of fruits, vegetables, maize, groundnuts, coconuts, roots and tubers and coffee increased but that of sorghum, sugarcane, cocoa beans, ginger and rice decreased. Sugarcane and rice production which has significant impact on energy contribution, decreased by 39 % and 36 % respectively.

Agricultural feedstock production suitable for Ethanol

The 20 year annual average production for molasses was 131,004 tonnes; cassava 43,300 tonnes; and sweet potatoes 5,721 tonnes. The potential ethanol (annual average) that can be theoretically produced from molasses is 32.75 million litres; 7.79 million litres can be produced from cassava; and 0.85 million litres from sweet potatoes. Figure 4 depicts that molasses is the best feedstock for ethanol production in Fiji. Cassava production recently surpassed the production of molasses because there was continuous decline in production of sugarcane as shown in Figure 1 however cassava is primarily a source of food in Fiji; whereas molasses is a by-product of which 90% is exported.

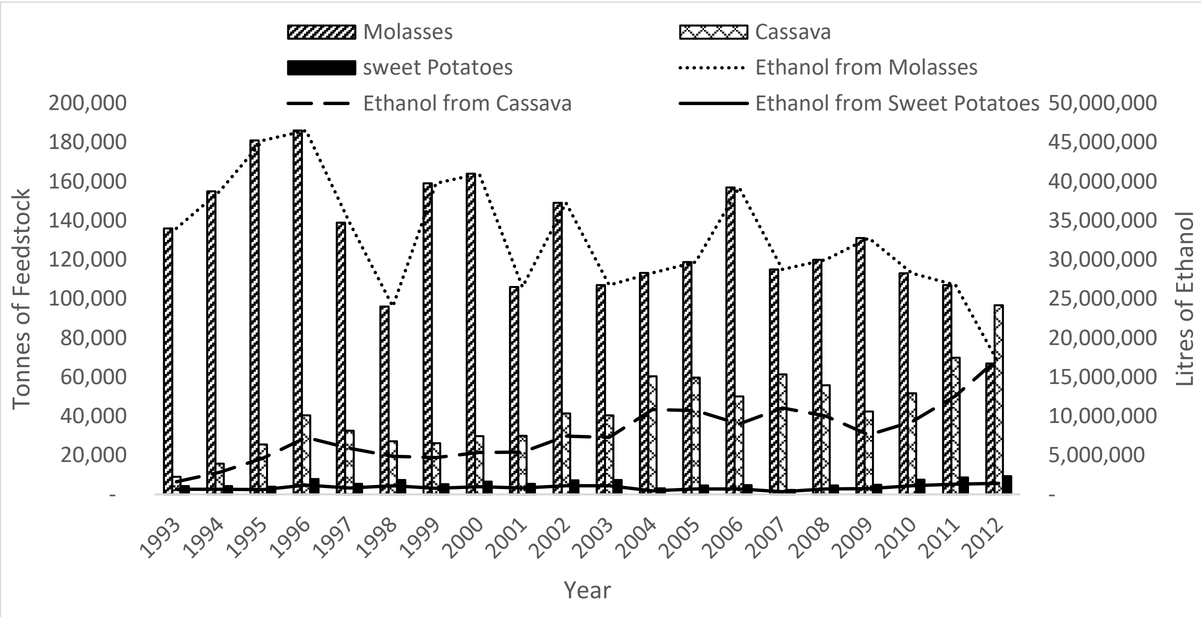
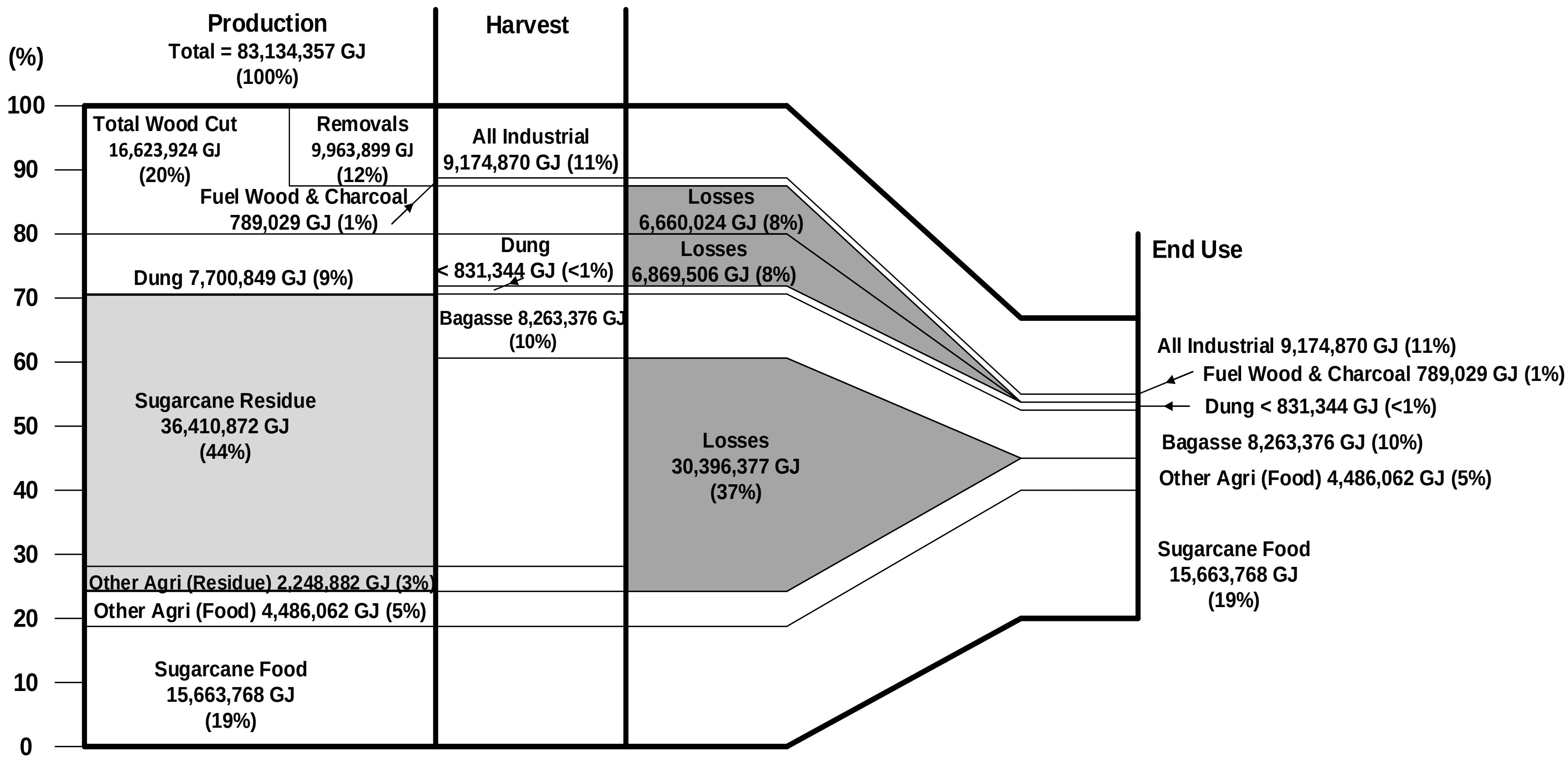


Figure 4: Production of feedstock and potential ethanol production

Table 2: Five year annual average crop production, estimated crop residues and energy potential (1993-2012)

Crop Category	Annual Average Crop Production (tonnes)		Crop Energy (GJ)		Annual Average Residue (tonnes)		Residue Energy (GJ)		Total Energy Content (Crop + Residue) (GJ)	
	1999-2003	2008-2012	1999-2003	2008-2012	1999-2003	2008-2012	1999-2003	2008-2012	1999-2003	2008-2012
Fruits	35,761	37,992	114,436	121,576	71,522	75,985	936,943	995,401	1,051,379	1,116,977
Vegetables	16,889	18,399	54,044	58,877	16,889	18,399	101,333	110,395	155,377	169,273
Maize	720	815	10,581	11,978	1,008	1,141	13,100	14,829	23,681	26,807
Groundnuts	212	284	5,305	7,100	446	596	7,130	9,542	12,435	16,642
Coconuts	162,240	207,750	3,244,800	4,155,000	53,539	68,558	696,010	891,248	3,940,810	5,046,248
Roots and Tubers	43,919	67,970	241,555	373,833	17,568	27,188	96,622	149,533	338,176	523,366
Sorghum	30	25	438	370	42	35	542	459	980	829
Sugar cane (000)	3,291	1,979	17,442	10,490	5,265	3,167	40,545	24,386	57,987	34,877
Cocoa, beans	16	7	253	109	16	7	243	105	496	214
Coffee, green	14	16	108	125	14	16	202	233	310	358
Ginger	2,934	2,560	9,388	8,193	1,173	1,024	7,041	6,145	16,428	14,338
Rice	14,688	9,366	215,911	137,680	60,220	38,401	806,948	503,048	1,022,858	640,728

Production figures were obtained from FAOSTAT (FAOSTAT 2014) and waste factor and energy content values were obtained from Refs. (Hemstock and Hall 1995, 1997; Amoo-Gottfried and Hall 1999; Rosillo-Calle et al. 2006b). Roots and Tubers consist of potatoes, sweet potatoes, cassava and yams.



Based on annual average (1993-2012) FAOSTAT (www.fao.org)

The scale is based on the total biomass harvested in agriculture and forestry.

Figures in parenthesis indicate % total production

PJ = 10^{15} J = 10^{6} GJ

Total may not add up due to rounding

Figure 5: Biomass energy flows in Fiji Annual average (1993-2012)

Available biomass end-use analysis

Agricultural crop resources

Total crop energy available is 58.6 PJ which is around 71 % of the total biomass production as represented in figure 5. The total food production was 20.0 PJ and total available crop residue was 38.6 PJ. It was noted that agriculture provides the highest source for biomass energy from which 30.39 PJ is lost or unutilized.

Ethanol Potential

Total theoretical ethanol production potential (annual average) from molasses is around 32.75 million litres (figure 4) which is approximately 32% of the total petrol (gasoline) imported in Fiji in year 2010. The average demand for ethanol in Fiji is around 8 million litres (Nakavulevu 2013). Thus the surplus 24.75 million litres of ethanol can be exported. As per the August 2014 Ethanol price of US$ 2.27 per gallon (Anonymous 2014a), Fiji has a potential to generate approximately US14 million dollars by exporting surplus ethanol produced from molasses. If sugar export becomes unattractive due to EU's decision to cut subsidies and sugar production is limited to local consumption only, it would leave 1,378,998 tonnes (Khan 2011) of sugarcane which could potentially produce 96.5 million litres of ethanol which is 96.5% of the motor spirit imported in 2010. The decline in sugarcane production from 2010 is significant (44%) but it still does not pose any threat to the ethanol production. The E10 blending presently demands approximately 10 million litres of ethanol which the present by-product molasses production will be able to meet. However for future ethanol production for the use in possible flex fuel vehicles or for the export market, an increase in cane production should be encouraged to establish long term stability.

4. Discussion

Energy production

The potential energy theoretically available from agriculture, livestock and forestry is 83.13 PJ as shown in Figure 5. However, only around 47% of the theoretical available biomass energy is used in the material form such as fuel, food timber etc. The other 53% is unused due to losses during harvesting and processing, charcoal conversion and residue losses from agriculture and forestry. A total of 8.98 PJ of biomass was directly used for energy as presented in Figure 5.

Total sugarcane residue comprises of 44% of the total biomass energy theoretically available from harvesting as shown in Figure 5, while wood comprises of 20%, dung 9% and other agricultural crop residue comprises 3%. Sugarcane residues are by far the most encouraging source of energy theoretically available with an energy content of 36 PJ which is 86% of the total energy consumed in year 2004.

Total annual average ethanol production potential is 41.39 million litres of which 79% is from molasses, 18.8% from cassava and 2.2% from sweet potatoes. The theoretical energy content of the potential ethanol that can be produced in Fiji is 879.65 PJ (*with a conversion factor 21.25 MJ/L* (Harvey 2010; Dunlap 2014; Wikipedia 2014)). If current sugarcane production is only used for local sugar production and ethanol production, a total of 129.25 million litres of ethanol can be produced - this is roughly equivalent to Fiji'scurrent motor spirit use.

Biomass energy utilization and losses

In Fiji, sugarcane bagasse meets the energy requirement of 4 sugar mills and surplus for grid electricity. An average of 886,628 tons of bagasse is used annually to generate 8.26 PJ of energy. 8 biogas digesters operate using livestock dung for producing biogas for cooking and lighting with the resulting digestate being used as a soil improver or food for milkfish production. However, despite many successful projects, the technology is still not widely used and only less than 1% (0.72 PJ) of available potential is utilized.

Total losses account for 53% of the total biomass theoretically available. The energy content in the losses amounts to 40.5 PJ as shown in figure 5. Losses can be categorized as conversion losses and unutilized residues. Conversion losses totalled 6.6 PJ which was lost during roundwood harvesting and processing. Dung and agricultural residues are unutilized biomass resulting inlossed of 6.86 PJ and 30.89 PJ respectively. This energy is equivalent to 90% of the energy consumed in 2004. Currently the sugarcane residue (excluding bagasse) is either left in situ or burnt in the field which only creates pollution and wastes material which could otherwise be used with bagasse.

Opportunity for improved utilization

Total annual production of agricultural residues and dung per capita was 44 GJ and 8.8 GJ respectively. Only 10.79% (0.83 PJ) dung and 21% (8.2 PJ) agricultural residue was utilized which is very low. More could be utilised if communities and household understood the benefits of using biogas digesters.

The recoverable forestry residue theoretically available is 6.66 PJ which is equivalent to 444 metric tons of wood. The recoverable forestry residue and agricultural residue together forms a major potential energy source but it is common practice to burn these residues on site to clear the area.

Sugarcane residues (leaves and cane tops) hold a significant amount of energy which could also be used with bagasse in the sugar mills (cogeneration) to generate electricity and export to national grid. This will reduce the use of fossil fuels and its emissions.

Sugarcane molasses also holds a significant amount of energy if transformed into ethanol. Currently 90% of the by-product which is exported which could be used to produce ethanol and blended with imported gasoline (E10), thus reducing gasoline importss by around 10%, leading to substantial savings.

5. Conclusion

This shows that the largest portion of biomass energy is from agricultural crops and the largest use of biomass in Fiji is as food source (sugar), followed by industrial wood and bagasse. It has also been emphasized that ethanol has a bright future in Fiji and sugarcane molasses can easily meet the local (E10) demands.

Appropriate planning and support at national and local levels (including solving land tenure issues) could lead to biomass energy being the most important renewable for Fiji's energy sector. The utilization of sugarcane residues by sugar mills will enhance electricity generation which can be exported to grid. This will contribute to a reduction in petroleum usage and carbon emissions.

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