IS THERE PROFIT IN CANE TRASH? ANOTHER DIMENSION TO THE ASSESSMENT OF TRASHING VERSUS BURNING

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Abstract

The development of a holistic model to assess the long-term economic effects of trashing versus burning provides the foundations for assessing the potential profits from sales of trash to a mill. The costs of trash delivered under various circumstances are compared with the cost of coal of equivalent energy. Numerous factors influence the cost competitiveness of trash but it is evident that, in some circumstances, there is a win-win situation for millers and growers if millers buy trash instead of coal. In other circumstances the agronomic value of the trash may be greater than its value as a fuel. Developments in energy technologies are likely to expand the opportunities for profitable trash sales, making it important to have a decision-support model for assessing long-term effects and profits. This paper presents one such model and gives perspectives on opportunities for future sales of trash.

Keywords: trash, baling, model, agronomy, burning, energy, fuel

Introduction

The value of trash as a source of energy has increased steadily in response to increasing energy prices, and the growing concerns regarding fossil fuel depletion and environmental issues, climate change in particular. In addition, world-wide aversion to pollution caused by cane burning has prompted a number of countries to set targets for reducing the amount of cane that is burnt. This pressure to reduce cane burning, together with concerns regarding existing energy usage, has encouraged interest in alternative uses for trash.

As market supply and demand dynamics change, the value of trash as a renewable energy source is increasing. However, the costs of harvesting unburnt (green) cane and collecting the trash have to be considered holistically before a decision on the cost-benefit of selling trash can be made.

In South Africa, a long-term trial of trashing versus burning continues to assess the impacts of these alternatives and has improved the understanding of the mechanisms affecting the results (van Antwerpen *et al.*, 2001; van der Berg *et al.*, 2006). These agronomic insights and others were incorporated into a spreadsheet model that attempted to assess a multitude of factors influencing the decision on whether to trash or burn (Wynne and van Antwerpen, 2004). Such analysis is critical to an assessment of the cost of recovering trash, because detailed economic costing must take into account long-term effects on soil fertility, water use and cane pests.

Some of the issues addressed by the model include:

- Relative costs of manual harvesting of burnt and green cane
- Extended delays and increased rates of cane deterioration due to burning
- Long-term yield decline

- Nutrient recycling
- Herbicide cost savings due to weed suppression by trash blankets
- Water saving and associated yield increases, or irrigation cost savings, due to trash blankets
- Loading and transport costs as affected by additional trash on green cane
- Milling costs and recoveries as affected by extraneous matter and cane deterioration.

This paper has adapted the spreadsheet model to include an assessment of the economic benefit of harvesting trash for use as an alternative to coal in the sugar factory. The sections that follow include reviews of recent coal price trends, trash collection studies in various countries, future trash demand and finally of trash delivery modes. The outcomes of these reviews were incorporated into the spreadsheet model, the results of which are presented, followed by a discussion and conclusion.

Review of recent coal price changes

The average domestic price of coal increased significantly in the past two years (Figure 1). In a submission to the Competitions Commission (Case No: 82/LM/Oct06), the causes for this price rise have been given as:

- Increased world demand for coal, accompanied by increased export capacity of Richards Bay Coal Terminal. These factors make it possible for coal producers to export coal and to increase domestic prices up to export parity prices.
- Increased demand for coal for domestic cement production, thus significantly increasing the domestic demand for coal.
- 'Commodification' of coal such that sales are based on energy value without concern for coal size. This has allowed small coal (duff) to be exported, whereas it was previously diverted to the domestic market at a lower price.

The nature of these causes suggests that the recent increases in price are unlikely to be reversed. Future planning should therefore be based on the increased prices. By March 2008, following coal shortages at Eskom and declining supplies from China and Australia, the Richards Bay price had reached R885/t, thus more than doubling in less than a year. This peak is possibly temporary, but it illustrates the levels to which the price of coal can rise. In addition to the increase in coal price, there has been an increase in the cost of transporting coal. These factors confirm the need to investigate coal alternatives such as trash, and consequently the need for a decision support model to clarify circumstances that make such a substitution economically viable.

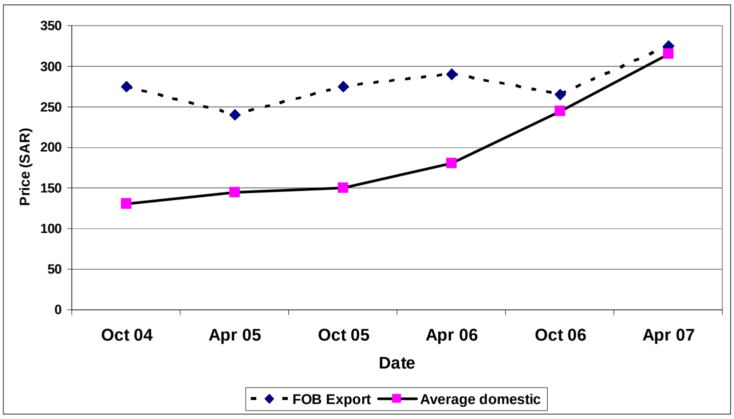

Figure 1. Trend in domestic price of thermal coal compared to export price (data from Competitions Commission Case No: 82/LM/Oct06).

Review of trash collection studies in various countries

Brazil

Comprehensive Brazilian studies, partly funded by the United Nations Development Fund, give substantial information on trash harvesting under Brazilian conditions (Hassuani *et al.*, 2005). Some findings are summarised in Table 1.

Table 1. Summary of residue quantity and composition from Brazilian trash study (Hassuani *et al.*, 2005).

Item		Quantity	Units
Residue ratio	(average)	140	kg(dry residue)/t stalks (wet)
	(range)	110-170	
Residue composition			
Components:			
dry leaves		1	Ratios relative to dry leaves (wet basis)
green leaves		2.28	
tops*		1.05	
Water:			
dry leaves		13	% at harvest
green leaves		65	
tops		80	
K_2O:			
dry leaves		2.7	g/kg (dry basis)
green leaves		13.3	
tops		29.5	
bagasse		1.7	
Na_2O:			
dry leaves		123	mg/kg (dry basis)
green leaves		128	
tops		119	
bagasse		45	
High heat value:			
dry leaves		17.4	MJ/kg (dry basis)
green leaves		17.4	
tops		16.4	
bagasse		18.1	

*Unlike in South Africa, 'tops' refers to the top of the stalk without associated green leaves.

The relatively high K and Na content of field residue compared to bagasse raises concerns about possible 'glass' formation during burning of residues. However, one mill experimented with 100% trash (tops included) as boiler fuel for more than a month and found no deleterious effects in terms of erosion or molten ash deposits in the boiler. The fuel had been cleaned to remove soil prior to baling in a specially modified baler (Leal, 1995).

The Brazilian trials involved various approaches to harvesting residue. Whole stalk harvesting (by machine) was abandoned because the machines could not operate effectively in green cane when yields exceeded 70 t/ha. Chopper harvester trials involved three levels of trash separation (controlled by fan speed) in conjunction with baling of trash deposited infield, or recovering trash from the partially cleaned cane by dry cleaning at the mill. Table 2 shows summarised results.

Table 2. Summary of harvester and dry cleaner performances in Brazilian trash study (Hassuani *et al.*, 2005).

Harvester fan setting	Normal	Slow	Off
Harvester cleaning efficiency (%)	75.5	29.2	5.5
Load per infield transport unit (t)	6.0	3.6	2.8
Truck load density (kg/m^3)	410	270	240
Prototype dry cleaner performance (t/h)	210	150	111
Extraneous matter prior to dry cleaning (% wet)	7.1	12.8	23.0
Dry cleaner separation efficiency (% dry basis)	46	45	60
Pol losses (% of pol prior to dry cleaning)	1.12	2.56	4.90

These results emphasised the high cost of transporting trash-laden material because of its low bulk density. The option of separating the trash in-field, partially drying it and then baling it reduces the transport costs. Various baling and bale-breaking systems were tested. Machines that produce rectangular bales proved better than those producing cylindrical bales, because the rectangular bales were of higher densities and their shape was better for transport and storage. Performance data of the best machines are indicated in Table 3.

Table 3. Performances of selected baler and bale breaker in Brazilian studies (Hassuani *et al.*, 2005).

Baler Performance	
Tractor power requirement (kW)	67
Fuel consumption (L/t dry trash)	1.6
Baling rate (t/h at 13% moisture)	9.1-9.8
Bale density (kg/m^3 dry)	175
Bale size (m)	0.8 x 0.9 x 1.9
Trash recovery efficiency (%)	56-84
Bale breaking and shredding	
Power per unit (kW)	82
Rate per unit (kg/h)	1000
Number of operators per unit	3

Bale breaking and shredding are needed if existing bagasse feeders are to process the trash effectively. The power requirement would be reduced if it was not necessary to match the particle sizing of bagasse.

A summary of relative costs as determined in the Brazilian work is given in Table 4.

Although extensive research has been done in Brazil to develop best methods for collecting trash, very little is done in practice (personal communication[1]).

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Table 4. Relative costs of trash collection as determined in Brazilian trials (Hassuani, 2001).

Operation	% of trash cost
Raking	3.2
Baling	21.3
Bale collection and loading	7.7
Infield haulage	6.4
Bale transport	10.5
Unloading	2.8
Trash shredding at mill	4.8
Agricultural impacts*	
Additional herbicide, fertiliser, etc.	30.2
Soil compaction	13.0
Total	100
US$/t dry trash (2001 price)	18.5

*Assumes 84% removal of trash. These agricultural costs would be much less if only 50% of trash was removed.

Colombia

An assessment of potential for deriving energy from cane trash in Colombia (Cock *et al.*, 2000) generated the following information:

- Residues constitute more than 30% of the total biomass at harvest.
- The moisture content decreases by 3-5% (absolute) per day when left in the field.
- Density of loose residues is less than 100 kg/m^3 but this can be increased to 600 kg/m^3 by compaction.
- The energy value is 10 MJ/kg at 35% moisture.
- The estimated cost (year 2000) for collection and delivery ranged from US$ 7.4 to 11.7/t.
- To compete with coal this cost had to be less than US$ 8/t at 35% moisture, or less than US$ 4.3/t at 65% moisture.

India

Paull and Krishnamurthy (2007) reported on baling trials on small farms in India. The trials involved the development of custom-designed mechanical rakes and the eventual use of tractors with ‘creeper’ gears required for slow speed. Commercial balers were not robust enough to withstand the extreme abrasive conditions. Square bales proved more suitable than cylindrical ones and a baling rate of 3.14 t/h (wet basis) was achieved.

South Africa

In South Africa trash is not harvested intentionally. However, trials were done in the late 1980s to assess the impact of bringing in various amounts of trash with the cane so as to increase bagasse supply (de Beer *et al.*, 1989; Reid and Lionnet, 1989; Purchase *et al.*, 1990). Four harvesting treatments were compared (all hand harvested), ranging from burnt and topped cane (normal procedure) to green cane with no removal of tops and trash (i.e. the whole cane). Extensive measurements of cutting, loading and transporting were made and enough cane was harvested for each treatment to run a factory for three hours. The resulting productivity data are summarised in Table 5.

Table 5. Productivity of men and equipment working with different harvesting techniques (Purchase *et al*., 1990).

On total mass basis	Burnt & topped	Whole cane
t/man h (cut & bundle)	1.06	1.51
t/trailer (in-field)	5.17	3.60
t/hilo	26.0	18.2
Loading rate (t/h)	43.2	33.6
On clean stalk basis		
t/man h (cut & bundle)	1.03	1.17
t/trailer (in-field)	5.00	2.80
t/hilo	25.2	14.1
Loading rate (t/h)	41.8	26.1

Harvesting technique affected the cost of cutting but had a bigger effect on the cost of loading and transporting. On a clean stalk basis, payloads with whole cane were 44% less than those with burnt, topped cane, and loading rates were 49% lower. This problem of high transport costs for trashy cane was also encountered in the Brazilian studies (Hassuani *et al*., 2005). The reasons for difficulties in loading and transporting whole cane are evident when the composition of this cane is contrasted with burnt and topped cane (Table 6).

Table 6. Composition of cane harvested by different methods. (Purchase *et al*., 1990).

Component	Burnt & topped	Whole cane
	Composition (% dry basis)	
Stalk	96.1	66.2
Tops	2.4	13.0
Trash	1.4	20.8
	Cane analysis (% wet basis)	
Pol	13.6	10.6
Purity	88.4	80.4
Fibre	14.4	21.6
Ash	1.1	2.8

The fibre content of the whole cane was 50% higher than the burnt-topped cane (Table 6); however, when the different tonnages harvested were taken into account the fibre yield (t/ha) was almost 100% higher, illustrating that bagasse supplies can be almost doubled by harvesting the entire plant. The amount of dry trash per ton of wet clean stalk was 153 kg(dry)/t(wet) which falls within the range (110-170) found in the Brazilian studies. Table 7 presents factory performance data, given that enough cane to run a factory for three hours was harvested for each treatment.

Table 7. Factory throughputs associated with different harvesting techniques (Purchase *et al*., 1990).

Component	Treatment			
	Green topped	Burnt topped	Whole cane	Burnt not topped
	Throughput (t/h)			
Cane	140	181	127	190
Fibre	30	26	27	28
Pol	16	24	13	25

Although fibre throughputs were similar across all treatments, the pol throughput was almost halved when the whole cane was processed. This represents a considerable increase in the cost of sugar production. In addition, the colour and turbidity of juice increased substantially (Reid and Lionnet, 1989).

Swaziland

Investment in co-generation at three mills in Swaziland was the subject of an analysis (US Agency for International Development, 1990) that indicated potential positive returns at one of the three mills (Ubombo). The analysis also indicated that supplementary fuel was necessary to achieve energy self-sufficiency (which included 8-10 MW for irrigation). Some trash is now baled for power generation at Ubombo.

Review of future demand for lignocellulose (trash)

In light of the increased price of coal, the most likely first demand for trash will be as a replacement for coal at sugar factories that presently buy coal. These factories buy coal because they need extra energy for back-end refineries, or because their bagasse is used by adjacent paper factories or by animal feed factories. The annual figures on coal purchases, as reported to the Sugar Milling Research Institute by the milling companies (e.g. Davis and Achary, 2006), do not necessarily reflect all coal purchases. Where bagasse is used to make paper, it is effectively exchanged for coal of equivalent energy content and this coal exchange is not reflected as a coal purchase. The amount involved in this exchange has therefore been estimated from published figures on paper manufacture. Table 8 shows an estimate of total coal use by sugar factories.

Table 8. Estimated coal usage at South African sugar factories.

Mill	Estimated coal purchases (t/an)	Coal : cane (t/1000t)	Added uses for bagasse/coal
Malelane	49 707	30.2	Import refining, animal feed and electricity for irrigation
Komati	1 171	0.6	
Pongola	7 152	5.0	Refining
Umfolozi	4 432	3.7	Refining
Felixton	104 590	46.0	Paper and irrigation
Amatikulu	2 533	1.6	
Darnall	595	0.4	
Maidstone	23 767	18.2	Animal feed and electricity sales
Gledhow	50 176	42.5	Paper and refining
Noodsberg	24 832	16.4	Import refining
Union Co-op	1 815	2.3	Wattle bark extraction
Eston	1 280	1.0	
Sezela			Furfural
Umzimkulu	141	0.1	
Total	272 192		

Based on energy values, approximately 483 000 tons of trash (dry basis) would be needed to replace the 272 000 tons of coal presently purchased. On average, if 50% of trash was collected (the remainder being left infield for agronomic benefits), then 33% of the total cane crop would be needed to supply the trash. This percentage rises to 116% and 107% for Felixton and Gledhow mills, respectively.

These figures illustrate the potential for a substantial market for trash. The economics of entering this market are assessed in the following sections. At present the benchmark for trash value is the price of coal but future developments in technology for trash use (e.g. trash-to-ethanol and trash-to-diesel) may increase the value of trash.

In the assessment that follows it is assumed that trash can replace the coal that is presently bought by sugar factories; it must nevertheless be noted that some factories have dedicated coal furnaces that could not burn trash without modification. Factories accepting trash would also incur costs of bale storage and bale shredding.

Review of trash delivery modes

Early concepts for trash harvesting involved leaving the trash on the cane for eventual separation at the mill, using a dry cleaning plant. An alternative approach is to separate the trash in the field and leave it to dry before baling for delivery. The latter approach is considered the most appropriate for South Africa because:

- Dry cleaning would involve re-negotiation of the cane sampling system and movement of the sampling point to enable sampling before dry cleaning.
- In-field cleaning eliminates any controversies associated with ownership of trash and payment for haulage. It also eliminates controversy as to compensation for cane losses during cleaning.
- Transport costs are reduced because the trash is partially dried and compacted.
- The drying prior to baling increases the total energy available from the trash. The energy available per unit mass of fibre increases by approximately 20% if the moisture is reduced from 60 to 30%.
- The trash can be sold to customers other than sugar factories.
- Baled trash can be stored on farms, probably at a lower cost than in large mill-based storage facilities, and with a lower fire hazard.

The spreadsheet model described by Wynne and van Antwerpen (2004) was adapted as a result of all of the above reviews with the objective of investigating the economic benefit of harvesting trash for use as an alternative to coal in sugar factories. The model is based on the premise that cane is currently burnt. The long term effect of trashing instead of burning is assessed together with the costs (financial and agronomic) of delivering trash to boilers. A new trash delivery cost assessment sheet involves modules for baling, loading and transporting. The overall profits or losses from delivering trash without burning are then computed for various values of trash.

Results

The importance of solar drying

Figure 2 shows the results of computing the recoverable energy per unit of dry matter in a typical trash mixture when the trash is burnt at different moisture contents. The shape of the curve will vary slightly for trash of different ash and brix compositions; however, the results emphasise the value of drying the trash before baling. In recognition of this, the computer model reflects low average daily hours for baling equipment to allow for delays caused by heavy dew and rain. The drying time between cutting and baling has generally been assumed to be 10 days. Periods longer than this are likely to result in losses due to consumption by insects and micro-organisms.

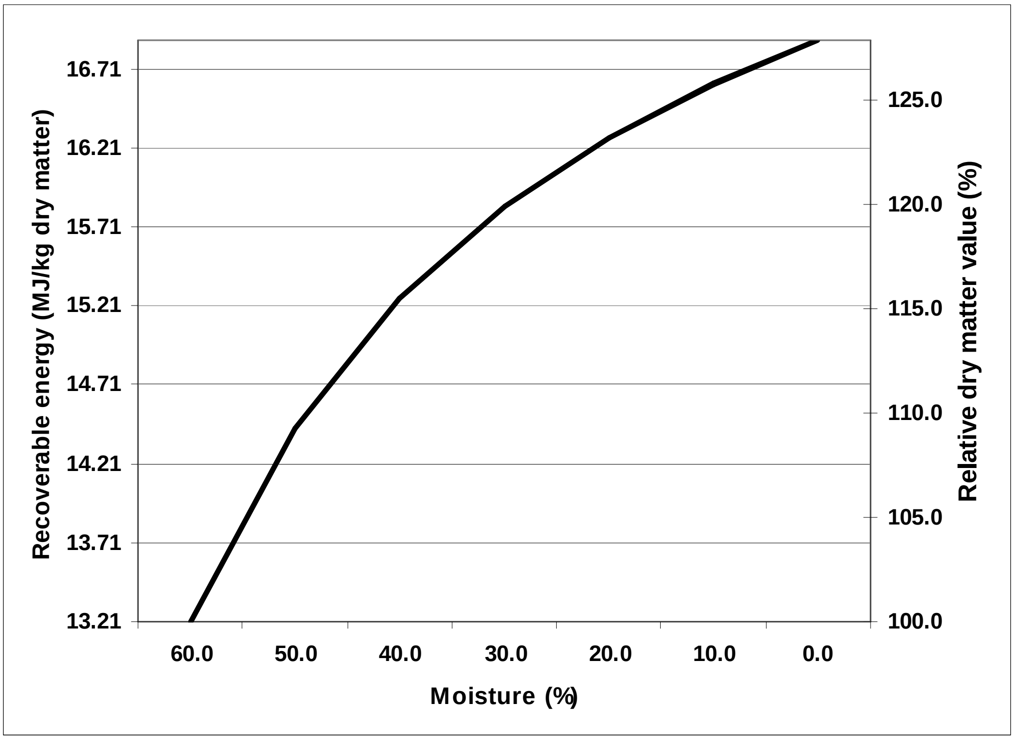

Figure 2. Recoverable energy and relative value per unit of dry matter for trash burnt at different moisture contents. (Recoverable energy (LCV) is calculated from the formula LCV (kJ/kg) = 18260 – 31.14*Bx % trash – 207.01*moisture % trash – 182.6*ash % trash, with the result being further calculated for expression in terms of dry matter.)

The influence of entrained soil

Although the inclusion of soil (ash) increases the total tonnage of trash, it decreases the overall energy value. For example, the addition of 5% soil would increase sales tonnage by 5%, but would decrease dry matter energy value per tonne by 12%, and overall revenue by 7%.

Coal equivalent prices

The coal equivalent value of trash at 30% moisture is shown in Table 9, assuming 27.5 MJ/kg for coal. It must be remembered that the energy value per unit of dry mass is strongly dependent on moisture content. Assuming the cost of coal and coal transport continues on an upward trend (Figure 1), and noting that the Richards Bay export price had reached R885/t in March 2008, it seems likely from Table 9 that the trash value at the sugar mill gate for the medium term will exceed R300/t of dry matter. The miller's costs of storage and shredding would have to be subtracted.

Table 9. Coal equivalent value of trash, assuming an energy content for trash equivalent to that containing 30% moisture.

Price of coal (R/t *delivered*)	Energy equivalent value of trash (30% moisture)	
	(R/t wet (30%) basis)	(R/t dry matter)
400	161	231
500	202	289
600	242	347
700	282	404
800	323	462

Simulation of farms on KwaZulu-Natal coastal sands and Northern irrigated soils

KwaZulu-Natal dry land coastal sands

This simulation is based on an 800 ha farm. The reason for choosing the unlikely high area of 800 ha is that the baling machine needs to cover such an area to achieve economic performance (Table 11). In addition, this area involves an equivalent number of vehicles for burnt and trashed cane, whereas an area of 1000 ha caused the model to use an additional transport vehicle for trashed cane, giving an unrealistic comparison. Cane is cut at an average age of 14 months, 80% of the cane area is harvested annually and average productivity is 5.2 t cane/ha/month. When baling, trash equivalent to the mass of the tops (dry basis) is left infield for agronomic benefits. It is assumed that this amount of trash gives a little more benefit than burnt tops. The distance from the mill is 20 km. The rate of deterioration of sucrose in burnt cane is assumed to be 10% faster than that in trashed cane. An average temperature of 20.5ºC is used for calculating the rate of sucrose deterioration. The delays between burn (or cut) and crush are assumed to be 55 and 39 hours for the burnt and trashed cane, respectively.

Northern irrigated areas

Again the simulation involves 800 ha under cane but the average age at cutting is 12 months; area harvested is 90% and productivity is 9 t/ha/month. Some credit is calculated for savings of irrigation water due to a partial trash blanket (not common practice). Other assumptions are the same as those for coastal sands except that a temperature of 21ºC is used.

The summarised results of both these simulations are presented in Table 10, where the grower margins reflect only those costs that are relevant to the comparisons. Two scenarios are compared for each site: (a) burning vs trashing where the trash is left infield, and (b) burning vs trashing where some of the trash is baled and sold to the mill.

Table 10. Simulated differences in grower margins on dryland coastal sands and in Northern irrigated areas, for burnt vs trashed cane (a) without trash sales and (b) with partial trash sales from the trashed cane.

Scenario	Differences in grower margins* (trashed – burnt)					
	R/ha under cane		R/ha harvested		R/t cane delivered	
	Coastal sands	Northern irrigated	Coastal sands	Northern Irrigated	Coastal sands	Northern irrigated
(a)No trash sold	1 115	702	1 393	784	11.51	6.84
(b)Trash sold (R/t dry matter)						
100	16	210	20	234	-1.96	1.78
200	461	**935**	576	**1 039**	5.50	**9.23**
300	906	1 659	1 133	1 843	**12.95**	16.69
400	**1 351**	2 384	**1 689**	2 648	20.40	24.14
500	1 796	3 108	2 245	3 453	27.85	31.59

*Grower margins reflect only those costs that are relevant to the comparison between burning and trashing.

As expected, the results for ‘No trash sold’ show a bigger benefit from trashing on KwaZulu-Natal coastal sands than on Northern irrigated soils, arising from a bigger agronomic yield response to a trash blanket with the former. When trash is sold, the price received needs to offset the baling and harvesting costs, as well as any agronomic costs of removing the trash. Selling trash becomes viable when the margins received for the ‘Trash sold’ scenario exceed those received when no trash is sold. Table 10 suggests that, in terms of R/ha under cane, this point is reached for KwaZulu-Natal coastal sands at a trash price between R300 and R400 per ton dry matter, while for Northern irrigated areas it is slightly below R200. This difference is due to the relatively small negative effect of removing trash from irrigated areas and to the larger quantities of trash produced for sale. In the Northern irrigated areas the economically viable price is below the anticipated value of trash (discussed above), suggesting that good profit can be made from trash sales. In the case of coastal sands the trash has considerable agronomic value, such that its sale at R300/t (dry matter) is not profitable. An apparent anomaly is that, if only the 'R/t cane delivered' column is considered, it might seem worth selling the trash at R300/t but, because of reduced yields, a higher price is needed for profit in terms of ha harvested and ha under cane.

In the case of Northern irrigated cane, the quantity of baled trash can be increased substantially if it is decided to leave less trash infield; e.g. equivalent to the amount left on coastal sands (Table 11). However, further investigation is required in this regard to ensure the agronomic yield response associated with trashing is not unduly compromised.

Indicative costs and quantities for trash collection and delivery

Estimated costs are strongly influenced by the extent of annual use of the baling equipment. The adverse impact of using this equipment for small areas is illustrated in Table 11, where the cost/ton baled ranges from R142 to R184/t depending on whether the baler covers 800 ha or 250 ha. These costs are mainly estimates with very little actual measurement, particularly for the high cost item, which is baling. Where direct infield loading onto haulage vehicles is possible, the total cost would be reduced by 10-15%. The lower costs for the irrigated area relate mainly to higher utilisation of the equipment, made possible by drier weather and higher tonnages. Topographical limitations in coastal areas have not been accounted for.

Table 11. Indicative costs and quantities of trash harvesting and delivery for an indirect delivery system.

	Cost of bales (R/t dry basis)			
	Northern irrigated			Coastal
Area covered (ha)	250	500	800	800
Activity				
Raking	19	15	13	19
Baling	79	53	45	67
Infield loading	6	7	6	7
Infield haulage	14	12	13	12
Transloading	9	9	9	10
Road haulage	39	39	37	39
Twine	18	18	18	18
Total	**184**	**153**	**142**	**172**
Quantities				
Item	t/ha (dry basis)			
Residue left in field	5.2			3.6
Baled trash	8.2			5.6
Bales (dry mass) % cane (wet mass)				
Baled trash % cane	7.5			7.5

Discussion and Conclusions

Recent increases in the price of coal seem sustainable and justify close consideration of the sale of cane trash as a replacement for coal. Sugar factories with associated by-product activities could provide a ready market for the trash. This market would currently consume about one third of the marketable trash (assuming that 50% is not marketable because of its agronomic value when left infield). Increasing use of trash for electricity generation is likely to expand the market for trash. Further expansion is anticipated when new technologies for conversion of lignocellulose to liquid fuels are commercialised.

This preliminary assessment suggests that the coal-equivalent value of trash in the near future is likely to exceed R300/t (dry basis) and that the cost of delivering it will be about R170/t (dry basis) from dryland and R140/t from irrigated areas. (This costing omits costs of handling and shredding the trash at the factory which, in Brazil, represented 4.8% of the total cost of trash utilisation (Table 4)). Assessment of the long-term agronomic value of trash on coastal sands suggests that a selling price of R300/t is not attractive on these sands. In Northern irrigated areas, however, this price should realise a good profit. The temptation to sell trash off coastal sands for short-term profit must be carefully weighed against the long-term value of leaving it on the land.

It is emphasised that, although the model used for this assessment takes into account a multitude of factors, there are gaps in detailed information relating to some of the issues. The issue of how much trash can be removed economically under different circumstances is one that deserves priority focus in further development of the model. Despite the gaps, the model highlights emerging opportunities for profitable sales of trash while warning against indiscriminate sales without regard for agronomic value. It also highlights the need for shared ownership of baling machines to ensure economical usage.

Adaptation challenges

Challenges in adapting to the use of trash in place of coal include:

- Creating appropriate incentives for cane cutters to cut unburnt cane and clean it.
- Adapting the cane knife to make it a better tool for removing trash – e.g. fitting it with a ‘trashing ring’.
- Optimising baling systems – conventional hay balers are not ideal for cane trash; they need to be redesigned for greater robustness and abrasion resistance.
- Installation of bale storage and de-baling equipment at factories.
- Adapting boilers that have been designed to burn only coal.
- Developing analytical facilities for quality control, particularly moisture and ash analyses (continuous on-line methods are probably possible).

Information needed

Better information is required on:

- Costs of baling.
- Response of boilers to higher levels of K and Na in the fuel.
- Optimum quantities of trash required for agronomic benefits under different conditions.
- Long-term effectiveness of trash for weed control. (It is known that some stoloniferous grasses and vines are encouraged by a trash blanket.)

Impact on cane processing costs
If cane burning is stopped and trashing is combined with trash collection then the impact on factory performance should be minimal because there would be an incentive to remove tops and trash; their value as fuel would be higher than their recoverable value (RV) in cane. Advantages for millers would include fresher cane (not burnt), increased cane supply due to higher productivity of the supplying farms and a less expensive fuel than coal. Potential problems associated with the disposal of coal ash would also be eliminated. No attempt has been made to assess the economics of these effects. Without trash collection, the extraneous matter levels in trashed cane would be significantly higher than in burnt cane and would partly offset the benefits of trashing mentioned above.

Carbon credits
Carbon credits are paid only when the project involved would otherwise be uneconomic. It is therefore unlikely that such credits would be payable to all trash burning projects. They would be payable if they enable a mill to supply electricity which would otherwise be uneconomical. To avoid double claiming, the distribution of such credits between miller and grower would be subject to pre-agreement before credits would be awarded.

The value of the 'BT1' trial
This paper has drawn strongly on information emanating from the trashing vs burning trial (BT1 trial) at the South African Sugarcane Research Institute. Tribute is paid to the foresight of those who established and managed the trial over the past 69 years. The value of this long-term research is evident now that it is important to assess the implications of not burning and of removing some trash.

Acknowledgements

Anthony Domleo and David Ducasse of Illovo Sugar Ltd are thanked for useful information on trash collection.

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