A PRELIMINARY STUDY OF THE ENERGY INPUTS IN THE PRODUCTION OF SUGARCANE

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Abstract

An initial evaluation of costing data as a source of derived energy inputs in the production of sugarcane is attempted. Factors developed elsewhere for other crops, with local adaptations, are used to convert production inputs from Rands to megajoules per ton of cane. Comparisons of different farm sizes, and mill areas, in energy terms show that statistically significant differences exist, as they do between irrigated and rainfed farms. Under rainfed conditions fertilizers, fuel and machinery maintenance account for about 88% of the energy inputs, whereas under irrigation 94% of the inputs are found to comprise electricity, fuel, maintenance and fertilizers. The considerable scope for energy economy is indicated by the comparison of groups of farms with low and high energy inputs, and which have respectively less than half and more than twice the whole sample mean. The differences in energy input between five methods of weed control, varying from the full use of technology to manual labour only, also indicate the scope for energy economy in a systems approach

Introduction

The world is becoming increasingly short of energy. The pessimistic contention is that fossil fuel reserves will not last until the end of this century while the optimistic point of view confidently, and perhaps complacently, relies on man's ingenuity to provide man's energy requirements for all time. Between these two extremes lies the reality that energy is going to be in short supply and increasingly more expensive. Although agriculture is a relatively small direct consumer of energy, compared with industry, marketing and commodity distribution, it is likely to suffer the effects of energy shortages earlier and more severely because of the comparatively low value of its products.

The main objective of agricultural production, research and development in the two decades 1950-1970, when fuel was plentiful and cheap, was higher crop yields per unit area of land. This was achieved by high levels of fertilization and chemical plant protection, together with a minimum use of manpower and maximum mechanisation. That this was a logical policy is evidenced by the fact that a barrel of fuel then costing R1 has an energy equivalent of 4 000 man hours.

Increased cost of fuel and its inevitable reduced availability makes it necessary for agriculture to review its production methods and reassess its research and development objectives. An important pre-requisite of such a reassessment is reliable data on the inputs of production in terms of energy. It is the objective of this paper to make an initial evaluation of the usefulness of existing economic production data collected by the South African Cane Growers'[5] Association's Economic Advisory Service as a source of derived energy input units which can be used in energy analyses and budgeting at farm level in the South African sugar industry.

Method

There are no published data on direct measurement of the support energy requirements for the production of sugarcane, but methods have been proposed for converting the costs of crop production generally into energy terms. Using some of these methods, with appropriate adaptation to the local conditions, conversion factors have been derived and applied to production costs determined by the S.A. Cane Growers' Association.[5]. Capital and other indirect items of cane production costs have been omitted, leaving the following for conversion:

Labour

From the average cash earnings per unit of labour, provided by the S.A. Cane Growers' Association[5], and an estimate of labour input energy of 1 800 megajoules per unit per annum given by Leach[6], it is possible to convert wages to labour energy input. For the present purpose it was not considered necessary to take account of variations in labour costs between mill areas, farm sizes or the distribution of labour categories.

Herbicides

The costs of the principal herbicides and the proportions in which they are used in the sugar industry were obtained from the trade, and by applying the energy values for the different formulations as published by Green[3], it was possible to convert expenditure on herbicides into energy inputs.

Fertilizers

The calculations of energy inputs in the form of fertilizers were made in the same way. The cost per unit of nutrient and the proportions in which N, P and K are used in the industry were made available, while their estimated energy values have been published by Austin[1].

Fuels and Lubricants

The estimated proportions of petrol, diesel and lubricating oils used by cane growers were obtained from the trade, and the energy values of these products given by Leach[6] were used. R1 spent on fuels and lubricants was calculated to represent an input of 375 megajoules.

Machinery maintenance

Leach[6] has also related the energy input values representing depreciation and repairs to fuel consumption for tractors of different sizes, and similar relationships have been given for implements and equipment. In terms of these conversions R1 spent on fuel and lubricants was found to be associated with an energy input of 260 megajoules for the maintenance of tractors or vehicles, and 37,5 megajoules for implements or equipment.

Chemicals

Leach[6] has been able to relate directly the cost and energy values of chemicals other than herbicides and after applying appropriate exchange and inflation factors it has been possible to convert expenditure on plant protection chemicals into an energy input in megajoules.

Electricity

The tariffs for electricity vary so much according to locality and size of holding that no direct and simple conversion from cost to energy can be applied to individual farms. However, with advice from the Electricity Supply Commission a conversion of Rand to megajoules has been used to obtain a reasonable average estimate of electrical energy input.

Contracting

Expenditure on contracting work on agricultural operations has been converted at the large tractor rate.

These various conversion factors were then applied to the individual items of production cost given by the S.A. Cane

Growers' Association to provide a computer print-out of energy input in terms of megajoules per ton of cane for the year 1976/77.

The compilation of costs is done according to size of farm, by mill area, and whether the crop is rainfed or irrigated. Table 1 is a summary of the populations and costed sample numbers according to farm size, and whether the crop was rainfed or irrigated. The class intervals for farms from 0 - 40 hectares and over 480 hectares were omitted because the numbers in these classes were considered too small to be representative.

TABLE 1
Populations and sample sizes by farm size for rainfed and irrigated crops separately

Farm size class interval (ha)	Rainfed			Irrigated		
	Population	Sample	%	Population	Sample	%
0 - 40*	196	3	1,5	59	7	11,9
41 - 80	263	36	13,7	192	28	14,6
81 - 120	282	47	16,7	42	12	28,6
121 - 160	281	80	28,5	35	13	37,1
161 - 200	196	59	30,1	12	6	50,0
201 - 280	156	55	35,3	7	3	42,9
281 - 480	107	39	36,4	9	4	44,4
>480*	32	9	28,1	2	0	–
Totals	1 285	316	24,6	297	66	22,2

*0 - 40 and >480 size groups and Natal Estates data omitted.

In Table 2 are shown the populations and sample sizes by mill area. In two of the mill areas, numbers were considered too small to warrant being included alone in further analyses. Natal Estates with five returns was therefore omitted and Union Co-op with two was combined with Jaagbaan.

TABLE 2
Populations and sample sizes by mill area for rainfed and irrigated crops separately, excluding the 0 - 40 and >480 ha groups

Mill Area	Rainfed			Irrigated		
	Population	Sample	%	Population	Sample	%
Darnall/Doornkop/ Glendale/Melville	96	38	39,6			
Gledhow/ Chakas Kraal	88	30	34,1			
Amatikulu	118	48	40,7			
Tongaat/Canelands	86	32	37,2			
Eshowe/Entumeni	47	21	44,7			
Illovo	67	19	28,4			
Umzimkulu	148	39	26,4			
Melmoth	44	10	22,7			
Sezela/Renishaw	75	18	24,0			
Empangeni	87	18	20,7			
Felixton	74	11	14,9			
Umfolozi	129	13	10,1			
Jaagbaan & Union Co-op	226	19	8,4			
Natal Estates (excluded)	62	5	8,1			
Union Co-op (incl. with Jaagbaan)	52	2	3,9			
Nkwalini				35	18	51,4
Malelane				105	33	31,4
Pongola				157	15	9,6
Totals	1 285	316	24,6	297	66	22,2

With these adjustments the samples represented 25% of the rainfed farms in the industry and 22% of the irrigated farms.

Results and Discussion

The mean energy inputs per ton of cane produced for the different farm size class intervals as set out in Table 3 do not differ significantly within the rainfed and irrigated groups. However, the difference between the rainfed and irrigated means themselves is significant.

TABLE 3
Mean input energy in megajoules per ton of cane produced by farm size for rainfed and irrigated crops separately

Farm size class intervals (ha)	Rainfed	Irrigated
41- 80	556	738
81-120	550	862
121-160	544	995
161-200	583	1 034
201-280	534	701
281-480	578	516
Means	558	808

Statistical analysis of the mean amounts of input energy by mill areas which are set out in Table 4 shows that significant differences between mill areas do exist. In the three irrigated mill areas, only the difference between Pongola and Nkwalini is significant.

TABLE 4
Mean input energy in megajoules per ton of cane produced by mill areas for rainfed and irrigated crops separately

Rainfed	MJ/ton	Irrigated	MJ/ton
Felixton	413	Pongola	671
Tongaat/Canelands	451	Malelane	804
Gledhow/Chakas Kraal	475	Nkwalini	945
Darnall/Doornkop/Glendale/Melville	487		
Sezela/Renishaw	565		
Empangeni	571		
Umzimkulu	577		
Amatikulu	606		
Melmoth	619		
Illovo	629		
Jaagbaan & Union Co-op	635		
Eshowe/Entumeni	660		
Umfolozi	708		
Mean	557	Mean	807

The statistical analyses of these data suggest that the variability among individuals within class intervals and mills is not stable. Statistical tests are therefore only approximate, but the conclusions drawn are unlikely to be incorrect.

Order of magnitude of the results

Austin *et al*[2] calculated the total on-farm support energy required to produce irrigated sugarcane in the Pongola mill area to be 42 GJ per hectare. Using different basic data and methods the figure obtained for the same mill area in the present study is 54 GJ per hectare.

Hudson[4] calculated the on-farm support energy required to produce a ton of cane under completely unmechanised conditions to be 136 MJ and estimated the energy requirements of an "efficiently mechanised" system of production to be between 236 and 354 MJ per ton, presumably under rainfed conditions. In this study the lowest individual farm in the rainfed sample has an energy input of 116 MJ per ton and 14% of the rainfed sample are in Hudson's range.

Estimates by Leach[6] of the energy inputs for the production of sugar beet varied from 350 MJ for rainfed conditions to 722 MJ per ton under irrigation.

These estimates of energy input are of the same order as those obtained in the present study, which suggests that the methods and procedures used here are not unreasonable.

Farm size differences

Individual rainfed farm input values vary from half to twice the class mean, but the class means themselves, given in Table 3, do not differ significantly. The items from which these means have been calculated are set out in Table 5, and are also seen to be very similar. (Chemicals other than fertilizers and herbicides comprise mainly nematicides).

TABLE 5

Components of the energy input means in megajoules per ton for the six rainfed farm size class intervals.

Item	Farm size class interval (ha)					
	41-80	81-120	121-160	161-200	201-280	281-480
Fertilizers	171	193	198	200	184	184
Fuel and lubricants	186	153	161	172	164	179
Maintenance	151	122	134	141	131	148
Electricity	26	35	22	21	23	28
Labour	13	11	11	10	10	11
Contracting	6	26	3	11	4	4
Herbicides	5	8	8	9	10	9
Chemicals	0	1	8	17	7	14
Totals	556	550	544	583	534	578

The situation suggests that under rainfed conditions where yields are between 42 and 55 tons per hectare per annum, production inputs are very uniform, although in any particular group there may be individual growers using only half and others using twice the average input of energy to produce a ton of cane.

The difference between rainfed and irrigated energy inputs shown in Table 4 is statistically significant and, as indicated in Table 6, is mainly due to the higher energy input of electricity on the irrigated farm.

TABLE 6

Energy input in megajoules per ton of cane produced for various items on rainfed and irrigated farms

Item	Rainfed	Irrigated
Fertilizers	188	136
Fuel and lubricants	169	199
Maintenance:		
Tractors:	71	79
Vehicles:	47	59
Implements:	17	20
Equipment:	4	38
Total:	139	196
Electricity	26	226
Labour	11	8
Contracting	9	37
Herbicides	8	5
Chemicals	8	2
Totals	558	809

Fuel and maintenance inputs per ton of cane produced are also higher under irrigated conditions, while the fertilizer input is lower. Using the mean yields per hectare of 54 and 65 tons per annum for rainfed and irrigated cane respectively to obtain actual levels of fertilizer used per hectare, indicates that higher rates are applied under rainfed than under irrigated conditions.

Mill area differences

Statistically significant differences were found between rainfed mill areas and in Table 7 two of these areas, which differ considerably in terms of individual items and means, are compared. The distribution of farm size class intervals for the two areas are reasonably similar as shown in Figure 1, and it is probable that the higher inputs for the Eshowe/Entumeni area are due to a greater degree of mechanisation and the differences in liability for cane transport. These are suggested by the much higher inputs for fuel and maintenance.

TABLE 7

Energy input in megajoules per ton of cane produced for various items for the Tongaat/Canelands and Eshowe/Entumeni rainfed mill areas.

Item	Tongaat/ Canelands	Eshowe/ Entumeni
Fertilizers	169	228
Fuel and lubricants	135	220
Maintenance:		
Tractors:	59	80
Vehicles:	35	59
Implements and equipment:	14	39
Total:	108	178
Electricity	15	28
Labour	12	12
Contracting	3	4
Herbicides	5	9
Chemicals	3	2
Totals:	452	660

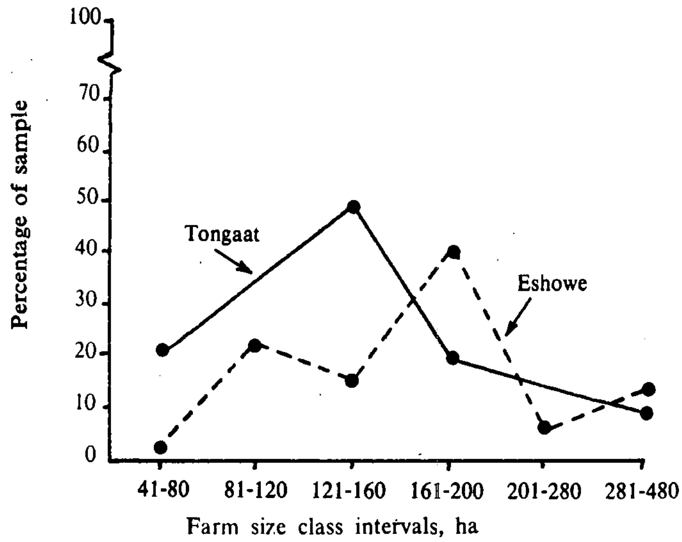

Figure 1: Distribution of farm sizes in the Tongaat and Eshowe mill areas.

In the analyses of the irrigated mill areas a significant difference was found between Pongola and Nkwalini. In Table 8 the component items are set out and they suggest that the dif-

TABLE 8

Energy input in megajoules per ton of cane produced for various items in the Pongola and Nkwalini irrigated mill areas

Input items	Pongola	Nkwalini
Fuel and lubricants	218	214
Maintenance:		
Tractors:	81	85
Vehicles:	70	63
Implements:	22	21
Irrigation equipment:	3	79
Total:	176	248
Electricity	148	175
Fertilizers	90	169
Contracting	17	123
Labour	9	9
Herbicides	2	6
Chemicals	10	1
Totals	671	945

ference is due to higher inputs in the Nkwalini area for maintenance, fertilizer and contractor costs and to some extent to lower yields.

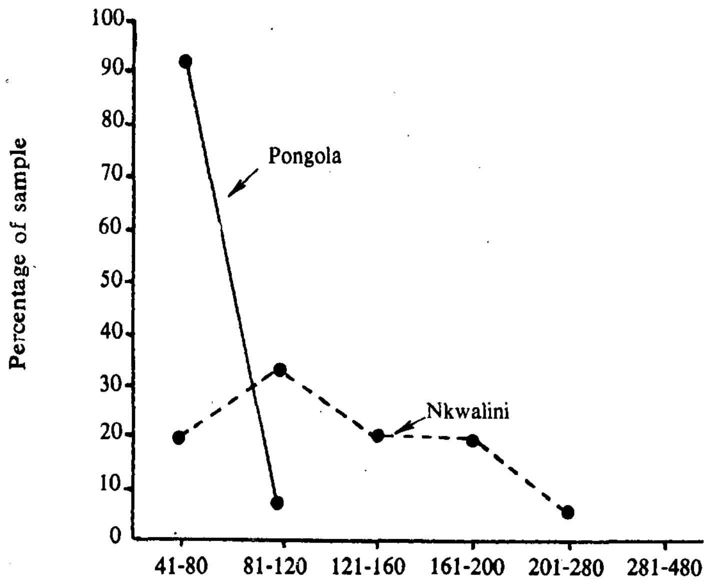

Figure 2: Distribution of farm sizes in the Pongola and Nkwalini mill areas.

Figure 2 shows that the distribution of farm sizes is very different in these two areas. This may be partially responsible for a 41% difference in total energy input between them being statistically significant when a 46% difference between the inputs for two rainfed mill areas with more similar farm size distributions (Table 7) do not differ significantly.

It is also of interest to note that fertilizer input is 88% higher per ton of cane produced and 41% higher per hectare in the Nkwalini mill area, in spite of the mean yield being 25% lower than that for Pongola.

Table 9 is a list in descending order of the energy inputs for all farms, rainfed and irrigated, showing that the first three items (fertilizers, fuels and maintenance) together account for 84% of the energy used. Electricity, which is the highest single input under irrigated conditions, is relatively little used on rainfed farms and overall is in fourth position. The remaining four items (contracting, labour, herbicides and chemicals) together account for only 7% of the total and are consistently low under all conditions.

TABLE 9

Energy inputs in megajoules per ton of cane produced for all farms

Fertilizers	181	84%
Fuel and lubricants	176	
Maintenance	143	
Electricity	55	9%
Contracting	15	7%
Labour	10	
Herbicides	8	
Chemicals	7	
Total:	595	100%

In an energy budget quoted by Leach[6] for corn production in the U.S. the same three items, fertilizers, fuel and maintenance, accounted for 82% of the total energy input, electricity was next in order, and labour, herbicides and chemicals together accounted for about 1%.

Average levels of inputs indicate that considerable economies could be achieved when energy becomes much more expensive or less available, but the potential for saving energy is more apparent when extreme cases are examined.

TABLE 10

Comparison of energy input items and yields of a low group, farms with energy inputs less than half the whole sample mean, and a high group, farms with energy inputs more than twice the whole group mean of 595 MJ per ton.

Item	Low group	High group
Fertilizers	126	256
Fuel	41	397
Maintenance	33	384
Electricity	11	261
Contracting	4	86
Labour	10	10
Herbicides	5	11
Chemicals	0	65*
Total:	231	1 470
Yield, tons cane/ha/annum	69	60

*one abnormally large user of a nematicide inflated this item in a small group.

Table 10 may be used to compare the items of energy input of a low and a high group. The low group consists of 17 farms, all rainfed, each of which had a total energy input of less than 300 MJ per ton, i.e. less than half the mean input of the whole sample of 387 farms. The high group of 11 farms, seven of which are irrigated, had total inputs exceeding 1 190 MJ per ton or more than twice the whole sample mean. The average yields of these two groups are 69 and 60 tons per hectare per annum respectively, suggesting a possible negative correlation between energy consumption and yield in these selected samples.

The higher input for electricity is due to the high group including seven irrigated farms in a sample of 11 but the inputs for fertilizers, fuel, maintenance and chemicals also appear to be excessive.

The exercise of energy economy may not necessarily or exclusively involve reduced consumption of the various input items such as fertilizer, fuel and electricity. The choice of methods and systems of production may also result in energy conservation and the options in weed control provide a good example.

Under "full technology" conditions the control of weeds can be achieved by the use of herbicides applied by tractor with perhaps one inter-row cultivation and a spot spraying by knapsack sprayer. At a lower technological level the substitution of knapsacks for tractor sprayers is feasible, as is the exclusive use of tractor cultivation. Finally there are hand hoeing and mule cultivation as non-technological methods.

These five alternatives are compared in Table 11 in terms of energy inputs based on the Experiment Station's weed control recommendations[7], the resource standards proposed by Thompson and Moberly[8], and the conventions referred to earlier in this paper.

The large difference between the three technological and the two non-technological methods is not surprising and is of the same order as the comparisons made by Hudson[4]. However, the relatively small differences between the three levels of technology are interesting. In the whole farm energy budget tractor operating costs, comprising fuel, lubricants and maintenance, constitute the largest single item, while herbicide energy input is relatively very low. It would therefore seem that economies should be sought more in those methods of weed control that involve tractors than in attempting to reduce herbicide usage *per se*.

Conclusion

Because the variability of data for farms within any particular group is not stable, more detailed analyses may be required in

TABLE 11

Comparison of energy input in megajoules per ton of cane produced for different weed control systems for a plant crop yielding 70 tons per hectare

Operations and materials	Weed control systems				
	Technological			Non-technological	
	Herbicides by tractor	Herbicides by knapsack	Tractor cultivation	Mule cultivation	Hand hoeing
Tractor spraying, pre-	2,1				
post-	2,1				
Tractor cultivating	3,1	3,1	28,2[1]		
Knapsack spraying, pre-		0,2			
post-		0,2			
spot	0,2	0,2			
Mule cultivation				9,2[3]	
Hand hoeing			0,7[2]	0,7	4,2[4]
Materials	23,0	23,0			
Totals:	30,5	26,8	28,9	9,9	4,2

[1] 9 passes [2] 8 man days/ha [3] 6(x3) passes [4] 49 man days/ha

future. However, the uniformity of means in spite of the variability of individuals within a group indicates that there is considerable scope for achieving economy in energy use on individual farms.

The results of this preliminary analysis of energy inputs derived from cost data are considered useful enough to justify further work. The accurate recording of cane production requirements in terms of physical inputs and costs which is being carried out in a project at La Mercy should lead to the improvement of the theoretical conversions used in this study. Improved conversions, derived under local conditions, would make energy input budgeting for individual farms a practical proposition and of increasing importance as the energy crises worsen.

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REFERENCES

1. Austin, R.B. (1975). Economy in the use of manufactured fertilizers. Agric Eng 30(3): 62-65.
2. Austin, R.B., Kingston, G., Longden, P.C. and Donovan, P.A. (1978). Gross yields and the support energy requirements for the production of sugar from beet and cane. J. agric Sci. Camb. Submitted for publication.
3. Green, M. B. (1976). Energy in Agriculture. Chemy Ind, 7 August, 1976: 641-646.
4. Hudson, J.C. (1975). Sugarcane: its energy relationships with fossil fuel. Span 18(1): 12-14.
5. Hudson, J.R. Personal communication.
6. Leach, G. (1976). Energy and food production. IPC Science and Technology Press pp. 137.
7. S.A.S.A. Experiment Station Weed Control Manual. 1975.
8. Thompson. G.D. and Moberly, P.K. (1976). Programme planning: a step towards improved sugarcane production. SASTA Proc 50: 40-49.