APPENDIX I: Modelling Terminology

Inter-cropping

The growth of two different crop types on the same area of land so that the canopies are intermixed and growth of both crop types occurs simultaneously.

Co-cropping

The sequential growth of two different crop types on the same area of land so that the second crop is planted after the first crop is harvested.

Crop Model

Montieth- "can be defined as a quantitative scheme for prediction the growth, development and yield of a crop, given a set of genetic coefficients and relevant environmental variables."

Sinclair et al.- "the dynamic simulation of crop growth by numerical integration of constituent processes with the aid of computers."

Mechanistic

Boote et al- "A mechanistic crop model is generally considered to be based on physiological and physical processes, and considers cause and effect at the process level. Material (C, N, water) and energy balance are usually included. The term *dynamic* is used to mean that the crop model responds to daily (or more frequent) changes in the environment."

Calibration

Boote et al- "is adjusting certain model parameters or relationships to make the model work for your site or sites."

Validation

Boote- "is determining whether the model works with totally independent data sets; that is, does it accurately predict growth, yield, and processes?"

Development

Boote et al- "the rate of progress through an organism's life cycle"

Ontogeny

Boote- "the time course of development through the phases of the life cycle"

Phenology

Boote- “the timing of visual events which mark the transition from one phase to the next”

<u>Definitions- Gasification Terms.</u>

ER (Equivalence Ratio)

Narváez et al- “air fed / stoichiometric air needed for total combustion”

APPENDIX II: Incidental Data Tables

Table II.1: Compositional Data and Heating Values for Biomass and Coal (Dry Basis).[a]

Feed stock	Proximate analysis percent by weight			Ultimate Analysis Percent by Weight						HHV	kg N	kg C
	Volatile	Fixed carbon	Ash	C	H	O	N	S	Ash	GJ t^{-1}	GJ^{-1}	GJ^{-1} [b]
Biomass												
Red Alder	87.1	12.5	0.4	49.6	6.1	43.8	0.1	0.07	0.41	19.3	0.07	25.7
Black Locust	80.9	18.3	0.8	50.7	5.7	41.9	0.6	0.01	1.05	19.7	0.29	25.7
Poplar	82.3	16.4	1.3	48.5	5.9	43.7	0.5	0.01	1.53	19.4	0.24	25.0
Hybrid Poplar [c]	-	-	-	50.9	6.0	41.9	0.2	0	0.9	20.3	0.08	25.1
Maple [c]	-	-	-	49.5	6.1	43.7	0.1	0	0.5	19.7	0.05	25.1
Douglas fir	87.3	12.6	0.1	50.6	6.2	43.0	0.1	0.02	0.10	20.4	0	24.9
Casuarina	78.9	19.7	1.4	48.6	5.8	43.6	0.6	0.02	1.59	19.4	0.30	25.0
E. grandis	82.6	16.9	0.5	48.3	5.9	45.1	0.2	0.01	0.49	19.4	0.08	25.0
Leucaena	80.9	17.5	1.5	49.2	6.1	42.7	0.5	0.03	1.51	19.1	0.25	25.8
Miscanthus [d]	78.5	-	2.3	48.6	5.9	-	0.3	-	-	-	-	-
Willow [d]	79.9	-	1.3	49.7	6.1	-	0.4	-	-	-	-	-
Sweet Sorghum [d]	77.2	-	4.7	47.3	5.8	-	0.4	0.1	4.7	18.9	0.21	25.0
Sugarcane Bagasse	73.8	15.0	11.3	44.8	5.4	39.6	0.4	0.01	9.91	17.3	0.22	25.9
Sugarcane Bagasse (Triangle Ltd.) [e]	-	-	-	41.8	5.3	40.2	0.0	0.00	3.8	17.2	0.00	24.3
Coal												
Zimbabwe [e]	-	-	-	69.9	3.9	5.3	1.9	2	13	30.3	0.63	23.1
West Kentucky bituminous	33.1	48.2	18.7	65.8	4.6	4.9	1.3	4.74	18.4	27.8	0.45	23.6
Illinois No. 6 Bituminous	37.5	43.4	18.1	65.3	4.2	6.6	1.0	4.55	18.3	26.7	0.38	24.5
Wyoming sub-bituminous	44.7	46.1	9.2	68.8	4.9	15.6	0.9	0.69	9.24	26.8	0.33	25.7
East Texas Lignite	44.6	38.9	16.6	61.0	4.5	15.8	1.1	1.08	16.6	24.4	0.44	25.0

a. Williams & Larson (1993)
b. calculated from data in table.
c. Craig & Mann (1996)- Maple = Wisconsin Maple
d. Sipilä et al, (1996); Táre, 1996, gives 18.6 GJ\t HHV(calculated mean Table 4.1.) Macedo, 1998, gives 7.74 GJ/t LHV bagasse.
e. Hard Coal- BP and bagasse Taken from John Thompson Africa bid (accepted) for new boiler at Triangle Ltd. “Fuel Specification” (1995).

Table II.2: Whole Plant Energy Content and Chemical Composition of a Number of Sweet Sorghum Varieties

	Ultimate Analysis (wt %db)				HHV[a]	LHV [b]	Ash
	C	H	N	S	GJ t^{-1}	GJ t^{-1}	%
Sweet Sorghum Varieties							
Brandes	44.61	6.25	0.20	0.31	16.7	15.7	3.2
Wray	43.51	6.10	0.12	0.04	16.9	15.9	1.8
Rona	42.56	6.19	0.16	0.05	16.9	15.9	1.6
Rio	44.40	6.22	0.39	0.11	16.7	15.7	2.2
M81E	44.28	6.25	0.18	0.09	17.2	16.2	1.6
MN1500	44.77	6.27	0.09	0.06	17.1	16.0	1.6
Dale	43.64	6.33	0.16	0.04	16.3	15.3	1.8
Theis	44.96	6.45	0.50	0.13	16.9	15.9	3.7
Keller	43.64	6.31	0.19	0.05	16.8	15.8	2.2
Keller (Zimbabwe) [c]	-	-	-	-	17.2	16.2	-
Cowley (Zimbabwe)	-	-	-	-	17.0	16.0	-
Mean	44.04	6.26	0.22	0.10	16.9	15.9	2.2
Standard dev. (n=9)	0.72	0.09	0.13	0.08	0.3	0.2	0.7

a. Source Türe et al, 1996.
b. LHV (Lower Heating Value or Net Calorific Value) is assumed to be approximately 6%<HHV i.e. 15.8 GJ/t; dry weight basis. See also Table II.1. in Appendix.
c. Analysis carried out on sweet sorghum samples prepared by Triangle Laboratories (March 1998)- see table 4.5.

Table II.3: Sugar & Yield Accumulation Characteristics of Five Sweet Sorghum Varieties (1997/98 Trial)

	Productivity		% Stem Fresh Mass						
	t_{fab} ha^{-1}	t_{dw} ha^{-1}	Purity	Fibre	BRIX	Pol	RS	TFAS	ERF
Sweet Sorghum [a]									
Booting [c]									
Keller	73.7	9.9	41.8	8.6	11.5	6.8	3.8	10.5	9.9
Monori Edes	84.2	7.4	41.3	12.2	7.2	3	8.8	11.3	10.6
IS19674	69	7.2	46.5	8.5	9	4.2	3.1	7.1	6.7
Cowley	80.1	6.3	75.3	13.5	10.6	8		8	7.3
Flowering									
Keller	73.1	9.9	70.3	9.5	12.2	8.6		8.6	8.1
Monori Edes	84.2	7.4	59.5	5.8	6.8	4	1.6	9.6	8.9
IS19674	69	7.2	50.7	11.2	9.6	4.9	3	7.7	7.1
Cowley	80.1	6.3	74.9	13.7	10.4	7.8	1.9	9.6	8.9
Rural 2			16.3	9	7.3	1.2	3	4.1	3.7
Milking									
Keller	73.1	9.9	81.2	11.9	12.1	9.8	1.7	11.5	10.8
Monori Edes			64.5	6.4	9.9	6.4	2.2	8.5	8.1
IS19674			51.4	10.8	11.9	5.7	3.3	8.8	8.2
Cowley			71.3	14	13.7	9.8	2	11.6	10.8
Grain Filling									
Keller	77.2	14	84	10.8	12.6	10.5	1.7	12.2	11.5
Rural 2			49.2	10.5	9	6.8		6.8	6.3
Sugarcane [b]									
Harvest	167.5	38.7	85.5	15.4	18.1	15.5	1.3	17	16

Notes:

a Data from 1997/8 CFC Project Sweet Sorghum Trials. (Mvududu, 1998)

b Taken from ZSA data for 1998. (Clowes, 1998)

c Crop Growth Stages in Chronological Order i.e. Booting ‘initiation of growth of reproductive organs’, Flowering ‘emergence of flowers’, Milking ‘early stages of grain growth’, Grain filling ‘final stages of grain growth’.

Table II.4: Energy Requirements for Agricultural Operations

Operation	Fuel		Labour	MTR [a]		Total (MJ/ha or t.km)
	MJ/ha	MJ/t	MJ/ha	MJ/ha	% of total	
Moldboard Plow	618		2.8	102	14	722.8
Disk harrow	579		1.6	55	9	635.6
Field Cultivator	286		1.4	42	13	329.4
No-till Planter	332		1.3	58	15	391.3
Grain drill	236		1.4	19	7	256.4
Combine, small grains	422		1.4	186	31	609.4
Bailing hay, rectangle	44	27	1.5	55	55	100.5
Bailing, hay, round	46	27	0.9	38	45	84.9
Mowing hay	95		1.4	28	23	124.4
Raking hay	93		2	46	33	141
Chopping silage	207	23	1.7	252	55	460.7

Source: Bowers (1992) op. sit. Bridges and Smith (1979)- Labour = 2.3 MJ per man-hour.
a MTR - Manufacture, Transport, & Repair.

Table II.5 Growth Sampling Data for CRS 1998/9 Trial

Date of Sampling	Days After Planting	Growth Stage	Treatment; Mean Standing Biomass: Fresh Weight g/m2	Fresh Weight STDS	Dry Weight g/m2	Dry Weight STDS	Moisture Content % (w/w)	LAI m2/m2	STEM DW g/m2 Main St.	STEM DW g/m2 Till.	LEAVES DW g/m2 Main St.	LEAVES DW g/m2 Till.	Seeds & Panicles DW g/m2 Main St.
Keller (Planted 24th November 1998)													
24-Nov-98	0												
03-Dec-98	9	Emerg.	0	0	0	0	0	0.00	0	0.0	0.0	0.0	0
15-Jan-99	52	Veg.	2313	850	177	10	92	2.00	162.8	0.0	160.3	0.0	0.0
28-Jan-99	65	Veg.	4573	1618	563	272	88	2.7	531.9	0.0	88.7	0.0	0.0
11-Feb-99	79	Boot	4415	1158	533	153	88	2.93	432.2	2.5	214.4	2.5	56.1
18-Feb-99	86	Flower	4013	862	601	155	85	3.35	475.2	4.8	206	4.8	83.9
25-Feb-99	93	milk	4908	1428	716	270	85	2.83	579.6	6.4	147	6.4	69.3
04-Mar-99	100	Dough	3461	1565	591	334	83	2.92	455.7	0.0	90.4	0.0	89.5
11-Mar-99	107	Dough	4515	1283	795	284	82	1.77	589.2	0.0	92.3	0.0	158.7
18-Mar-99	114	maturity	4788	1631	1083	467	77	1.29	758.9	0.0	85.8	0.0	192.2
25-Mar-99	121	maturity	4261	2613	0	0	100	na	na	na	na	na	na
Cowley (Planted 24th November 1998)													
24-Nov-98	0												
03-Dec-98	9	Emerg	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0
15-Jan-99	52	Veg.	1893	255	153	37	92	2.64	129.5	14.4	170.5	14.4	0.0
28-Jan-99	65	Veg.	3583	754	447	157	88	3.19	433.3	4.0	83.8	4	0.0
11-Feb-99	79	Boot	5463	517	695	143	87	4.24	644.6	5.4	306	5.4	43.4
18-Feb-99	86	Flower	6069	571	793	128	87	4.69	608.1	34.9	267.4	34.9	46.3
25-Feb-99	93	milk	5949	1285	819	267	86	3.03	729.9	0.0	228.9	0.0	59.6
04-Mar-99	100	Dough	6056	1244	1015	214	83	3.58	835	5.9	198.9	5.9	122.0
11-Mar-99	107	Dough	6497	1176	1242	285	81	3.58	1020.5	5.8	210	5.8	141.1
18-Mar-99	114	maturity	4971	1368	1205	380	76	3.18	0	5.2	254.2	5.2	218.4
25-Mar-99	121	maturity	4667	943	0	0	100	3.17	0	na	na	na	na
Keller (Planted 4th December 1998)													
04-Dec-98	0												
10-Dec-98	6	Emerg.	0	0	0	0	0	0.00	0.0	0.0	0.0	0.0	0.0
15-Jan-99	42	Veg.	1433	403	94	21	93	1.51	93.6	0.0	145.5	0.0	0.0
21-Jan-99	48	Veg.	3060	625	296	45	90	1.69	264.2	2.2	70.2	2.2	0.0
28-Jan-99	55	Boot	4247	1032	409	81	90	3.21	387	0.0	202	0.0	21.5
04-Feb-99	62	Flower	4657	679	562	99	88	2.77	480.1	0.0	191.3	0.0	38.4
18-Feb-99	76	milk	4565	750	609	43	87	2.81	501.4	0.0	200	0	54.0
25-Feb-99	83	Dough	4613	1529	809	262	82	1.85	678.9	3.0	134.1	3.0	70.4
04-Mar-99	90	Dough	4111	1795	1047	372	75	2.74	847.7	0.0	142.7	0	94.8
11-Mar-99	97	maturity	4543	1850	711	345	84	1.94	542.4	0.0	72.9	0.0	125.3
18-Mar-99	104	maturity	5068	1476	1012	467	80	1.72	727.7	0.0	102.8	0.0	184.6
25-Mar-99	111	maturity	3931	886	1167	248	70	0.00	806.7	0.0	0.0	0.0	199.8
01-Apr-99	118	maturity	4271	425	1326	5	0	0.00	898.3	na	0.0	0	199.3
Cowley (Planted 4th December 1998)													
04-Dec-98	0												
10-Dec-98	6	Emerg.	0	0	0	0	0	0.00	0.0	0.0	0.0	0.0	0.0
15-Jan-99	42	Veg.	1107	130	102	17	91	1.67	86.2	10.0	0.0	10.0	0.0
21-Jan-99	48	Veg.	2013	344	173	41	91	1.75	143.3	2.0	63.6	2	0.0
28-Jan-99	55	Boot	3943	487	426	77	89	3.56	395	13.0	367.4	13.0	13.0
04-Feb-99	62	Flower	4412	627	441	159	90	3.50	411.9	2.6	165.4	2.6	0.0
18-Feb-99	76	milk	4561	982	622	86	86	5.31	442.9	17.6	296.0	17.6	30.8
25-Feb-99	83	Dough	4536	645	839	84	81	2.94	728.7	3.5	245.8	3.5	65.8
04-Mar-99	90	Dough	4562	908	760	157	83	3.42	623.8	5.5	116.1	5.5	86.3
11-Mar-99	97	maturity	5588	1146	1058	168	81	2.72	868.1	0.0	197.5	0.0	136.8
18-Mar-99	104	maturity	5533	632	1067	273	81	3.28	816.2	2.0	110.7	2.0	185.2
25-Mar-99	111	maturity	4927	911	1135	227	77	2.76	858.4	246.8	246.8	246.8	195.6
01-Apr-99	118	maturity	5497	577	1503	20	73	2.4	1111	0.0	160	0	268.8

Notes: DW = Oven Dry Weight; STDS = Standard Deviation of the Population; Emerg. = Emergence; Veg. = Vegetative Growth Phase; St. = Stem. For Definitions of growth stages see Appendix I.
Field data collected by L. Nyabanga and his research team at CRS. Data input into spreadsheets (computer-based) by L. Nyabanga and E. Mvududu (SIRDC) using spreadsheet templates designed by J.Woods (KCL).
Collation and checking by E. Mvududu and J.Woods.

Table II.6 Correlation between Water Supply and Sweet Sorghum Yield

Kendall Rank Correlation Test (Yield versus water supply)

DM t ha^{-1}	mm	P	Q	P-Q		***DM*** (t ha^{-1})		***ha.mm***
4	286.5	28	0	28				
5.08	402.5	24	3	21	Mean	23.8824	Mean	561.5241
5.15	343.7	***26***	***0***	26	SE	2.0734	SE	30.2334
6.6	368.7	25	0	25	Median	24	Median	553.4
13	460.3	19	4	15	Mode	21	Mode	409.1
14.36	409.1	20	1	19	SD	11.1659	SD	162.8115
14.7	409.1	20	1	19	Variance	124.678	Variance	26507.5876
16	423	19	2	17	Kurtosis	-0.4918	Kurtosis	-0.2438
17	553.4	14	6	8	Skewness	-0.1034	Skewness	0.5014
20.9	409.1	18	1	17	Range	41	Range	653.1
21	638.2	8	9	-1	Minimum	4	Minimum	286.5
21	400	17	0	17	Maximum	45	Maximum	939.6
22	529.4	14	2	12	Sum	692.59	Sum	16284.2
22.6	552	***13***	2	11	Count	29	Count	29
24	617.6	8	6	2	Confidence	4.0639	Confidence	59.2563
27	483	13	0	13	Level(0.95)		Level(0.95)	
27	704.6	5	7	-2				
29	600	7	4	3				
30.3	656.6	***6***	***4***	2				
30.3	586.3	6	3	3				
30.8	560	7	1	6				
31	736.8	4	3	1				
31.7	526	6	0	6				
32	667	4	1	3				
32.5	580	4	0	4				
34.3	758.7	3	0	3				
40	939.6	0	2	-2				
44.3	815	1	0	1				
45	868	--						
		339	62					

S	277	sum (P) - Sum(Q)
K	0.6823	*** Z>2.58 (i.e. K is v. highly sig. diff. from zero)
Z	5.196	Kendall Rank Correlation Coefficient Pure = +/- 1.0
rev K	0.6873	<-revised due to 'tied data values in DM and mm
A	3	i.e. 0.5[2(2-1)+2(2-1)+2(2-1)]
D	3	i.e. 0.5[3(3-1)]

Stats analysis procedure from Wardlaw pp 190-196

Sweet Sorghum Percolator Test Data.

Table II.7: Experimental Percolation Velocity for Sweet Sorghum Bagasse (cv. Keller)

1st Experiment: Percolator Test Carried out on 16th March 99 at Triangle Mill using 1200mm sorghum bagasse and cold water.

Sample Point (mm)	1	2	3	4	5	6	7
1100	0	0	0	0	0	0	0
100	26	53	62	74	82	98	116
m/min	2.31	1.13	0.97	0.81	0.73	0.61	0.52
Avg m/min		0.91					

2nd Experiment: Percolator Test Carried out on 15th March 99 at Triangle Mill using 700mm sorghum bagasse and cold water.

Run No.	1		2		3		4	
mm	time	Time Diff	time	Time Diff	time	Time Diff	time	Time Diff
1200	15:57:13		16:10:22		16:22:43		16:41:20	
1100	15:57:36	00:00:23	16:11:00	00:00:38	16:23:20	00:00:37	16:42:03	00:00:43
1000	15:58:08	00:00:32	16:11:37	00:00:37	16:24:13	00:00:53	16:43:07	00:01:04
900	15:58:45	00:00:37	16:12:18	00:00:41	16:24:25	00:00:12	16:44:17	00:01:10
800	15:59:23	00:00:38	16:13:06	00:00:48	16:25:10	00:00:45	16:45:38	00:01:21
700	16:00:03	00:00:40	16:13:56	00:00:50	16:26:14	00:01:04	16:47:09	00:01:31
600	15:59:23		16:13:56		16:27:00	00:00:46	16:48:20	00:01:11
500	16:00:45	00:01:22	16:14:43	00:00:47	16:28:17	00:01:17	16:49:03	00:00:43
400	16:01:05	00:00:20	16:14:47	00:00:04	16:28:36	00:00:19	16:49:03	
300	16:01:05		16:15:07	00:00:20	16:29:02	00:00:26	16:49:03	
200	16:01:32	00:00:27	16:15:15	00:00:08	16:29:25	00:00:23	16:49:44	00:00:41
100	16:01:36	00:00:04	16:15:40	00:00:25	16:29:55	00:00:30	16:50:30	00:00:46
0								
Time last 0.4 m->		00:00:51		00:00:57		00:01:38		00:01:27
	m/min	0.41		0.36		0.21		0.24
Time last 0.7 m->		00:00:00		00:00:00		00:00:00		00:00:00
	m/min	0.45		0.40		0.19		0.21

Table II.8: Major Electric Motors at Triangle Mill

Motor	Power	Power Factor	Energy Cons	Process Rate	Energy Cons.
	KW		MJ h^{-1}	t_{cane} h^{-1}	MJ t_{cane}^{-1}
Slip Ring Motors					
Shredder	1800	0.89	6480	304	21.3
Knives (600 KW x 2)	1200	0.81	4320	490	8.8
Boiler 7&8 ID fans	222	0.85	799	490	1.6
Mill 1	333	0.85	1199	186	6.4
Mill2&3	600	0.85	2160	186	11.6
Mill 4&5	600	0.85	2160	186	11.6
Squirrel Cage Motors					
Boiler 10 ID fan	750	0.87	2700	490	5.5
Boiler 9 ID fan	600	0.89	2160	490	4.4
Boiler feed water pump	400	0.92	1440	490	2.9
Injection water pumps (250 KW x3)	750	0.82	2700	490	5.5

Base data from Vengesai (1999)

Table II.9: Harvesting & Delivery Costs for Sweet Sorghum (Section 26, 62 & CRS)

	Section 26		Section 62		CRS		Total		
Labour Categories									
	No.	Z$	No.	Z$	No.	Z$	No	Z$	£
Cutter Cook	1	50	0	0	0	0	1	50	1
Cutters	20	1028	40	2030	61	3187	121	6246	104
Trashing	20	999	45	2288	72	3662	137	6949	116
Carrying out	20	1029	45	2288	71	3662	136	6979	116
Drivers	4	332	2	149	7	746	13	1227	20
Chainmen	3	161	3	155	6	677	12	993	17
Meter Man	0	0	1	50	0	0	1	50	1
Supervisors	3	289	4	406	5	610	12	1306	22
Sub-Total	71	3889	140	7367	222	12543	433	23799	397
Transport Fuel (Diesel)									
	l	Z$	l	Z$	l	Z$	l	Z$	£
Labour	11	363	0	0	70	2310	81	2673	45
Sorghum	65	2310	71	2955	337	11121	473	16386	273
Sub-Total	76	2673	71	2955	407	13431	554	19059	318
Food (1 Meal)									
							kg	Z$	£
Mealie Meal							5	28.93	0.00
Beans							2	21.00	0.00
Cooking Oil (ml)							120	5.52	0.00
Salt							0.1	1.26	0.00
Sub-Total								56.71	0.95
Total		**6562**		**10322**		**25974**		**42915**	**715**

Source: Besler, E. (1999)

Notes: Summarised from Triangle Ltd. Bill for harvesting and transport of Sweet Sorghum from CRS and Sections 26 & 62 on the 17th March 1999.
Exchange rate as of March 1999- Z$ 60 = 1 GBP
Drivers (Tractors + Truck) & Chainmen for transport only
Diesel use recorded in litres @ Z$ 34.40 per litre

Table II.10: Sweet Sorghum Transport Costs, 17th & 18th March 1999, Triangle Ltd.

Section	Grower	Total Tonnes Weighbridge	Direct Haulage	Crane Loaded	Hilo Hauled	Distance
			Tonnage		t.km	km
26 Sorghum	1200	35.92		35.920	216	6.0
62 Sorghum	1210	35.54		35.540	519	14.6
CRS	1220	130.7	58.060	72.640	1162	16.0
Total		202.16	58.060	144.100	1897	9.4
Rate		2.82		6.26	3.13	
Total Haulage Costs	7409.77	570.09		902.07	5937.61	
Z$ per t.km	3.91					

Source: Bresler, E. (1999) (7)

Notes: Z$60 = GBP 1, therefore average transport cost = £0.065 per t.km

Table II.11: Example of Energy Sequestered in a Machinery Complement for Maize Production in USA.

Equipment	Weight (kg)	Energy (GJ)			
		Manufacturing	Transportation	Repairs	Total
Tractor	3976	345	35	169	549
Plow	966	83.8	8.5	82.1	174.4
Disc	2569	222.9	22.6	136	381.5
Planter	1462	126.9	12.9	54.6	194.4
Fertilizer	2025	175.5	17.8	66.8	260.3
Rotary hoe	982	85.2	8.6	51.1	144.9
Combine	5511	478.2	48.5	114.8	641.5
Total	17491	1517.5	153.9	674.4	2346

Source: Bowers (1992)- Manufacturing: 86.77 MJ/kg; Transportation: 8.8 MJ/kg; Repairs (average ratio of repair and maintenance to total energy = 0.55)

Table II.12: Life Expectancy for Commonly Used Machines

Machine	Wear out Life (h)
Tractor, Wheeled	12000
Tractor, Crawler	16000
Combines	3000
Corn harvesters... all tillage tools	2000
Planters, drills, mower	1500

Source: Bowers (1992)

Table II.13: Approximate Fertiliser Levels Applied to Various Crops (USA & Zimbabwe)

Crop Type	Nitrogen (N)	Phosphorus (P_2O_5)	Potassium (K_2O)	Total
		($kg\ ha^{-1}\ yr^{-1}$)		
Agricultural crops				
Maize[a]	135	60	80	275
Sorghum[b]	90	60	60	210
Soybeans[a]	20	45	70	135
Wheat[a]	60	35	45	140
Hay land[c]	20	40	40	100
Alfalfa[c]	0	75	150	225
Pasture[c]	15	40	40	95
Set-aside[d]	5	20	20	45
Sugarcane[f]	175	51	72	298
Energy Crops[e]				
Sweet Sorghum[g]	110	42	21	173
Sugarcane[f]	135	45	90	270
Sericea lespedeza	10	30	90	130
Switchgrass	50	60	60	170
SRF	60	15	15	90
SRF (N-fixing)	20	30	15	65

Source: primarily Ranney (1994)

a- approximate US average (USDA, 1991)

b- Average fertilisation levels derived from US state crop budget recommendations for grain sorghum from the states of Alabama, Georgia, and Virginia

c- Approximate average fertilisation levels derived from Tennessee and Virginia crop budget estimates for maintenance conditions. Establishment levels of fertiliser are higher

d- Set-aside land as used here includes crop land taken out of production and conservation reserve land. Some establishment of vegetative cover is assumed to require minimum fertilisation.

e- Oak Ridge National Laboratory (unpublished data base, 1992)

f- Agricultural crop data from Lewis, 1984, representing average application for Triangle, Zimbabwe, (500 kg Ammonium Nitrate (AN), 230 kg Single Super Phosphate, and 120 kg Potash, $ha^{-1}\ yr^{-1}$) yield 115 t_{cane} $ha^{-1}\ yr^{-1}$ Energy crop data from Legendre & Burner (1995) for a trial plot hybrid yield of 307 t_{fab} $ha^{-1}\ yr^{-1}$.

g- Actual data from 1997/98 sweet sorghum trials, Chiredzi, Zimbabwe; total above ground biomass yield of 80 fw t $ha^{-1}\ yr^{-1}$(yield achieved in 4 months crop growth).

Table II.14: Composition of Various Fertiliser Types

Fertiliser Type	Nutrient (%) (N : $P_2 0_5$: K_2O)
Nitrogen Fertilisers	
Ammonia (as direct fertiliser)	80:0:0
Urea	46:0:0
Ammonium nitrate[b]	34:0:0
Urea-ammonium nitrate	30:0:0
Ammonium sulphate (28% sulphur)	21:0:0
Others	48:0:0
Phosphorous fertilisers	
Single Superphosphate	0:22:0
Double Superphosphate	0:46:0
others	0:44:0
Potash fertiliser	
Muriate of potash	0:0:60
Mixed fertilisers	
Diammonium phosphate	18:46:0
Monoammonium phosphate	11:54:0
Compound D[a]	8:14:7

Source: Bhat, M.G. (1994)

[a] As used in our Zimbabwe Trials- this ratio refers to kg per 100 kg of compound D (Granulated), therefore 100kg of Compound-D contains 8kg N, 14 kg P_2O_5, and 7 kg K_2O. It also contains a minimum of 6.5% Sulphur (Manufacturer Windmill Co.)

[b] In Zimbabwe trials (Chiredzi) added as a top dressing (granulated) to supplement the N from the initial fertiliser input from Compound-D to ensure the total N applied was 100 kg / ha.

Pesticides

Table II.15: Average Energy Inputs for Pesticide Production (Two Estimates).

Class	Production Energy (MJ/kg of active ingredient)	Production Energy (MJ/kg of active ingredient)
Herbicide	215	264
Insecticide	245	214
Fungicide	356	168
Mean	272	215

Irrigation:

Table II.16: Overall Efficiencies for Electricity Generating Plants

Motor Size		Generating plant (%)		
hp	kW	Thermal	Nuclear	Hydro
35826	0.75-1.5	16	22	45
35916	1.5-3.7	17	24	48
35939	3.7-10.6	18	25	51
25+	18.6+	19	27	53

Source: Sloggett (1992) op sit. Economy Pumps, 1955; Boustead and Hancock, 1979.

Table II.17: Modern Irrigation Water Pumps and Their Characteristics

Pump Type	Lift (m)	Discharge Rate (m3/h)	Efficiency (%)
Centrifugal	up to 10	10-500	50-75
Turbine	10-500	10-500	70-82
Propeller	up to 3	500+	80-89
Mixed-flow	36009	500+	80-89
High-volume Turbine	8+	500+	80-90

Source: Sloggett (1992) op sit. Economy Pumps, 1955, Molenaar, 1956, and Aurora Pumps, 1977

Table II.18: Conveyance and Distribution System Efficiencies

Conveyance Facility	Efficiency (%)	
	Continuous flow	Intermittent flow
Main conveyance	87-95	50-88
Distribution	90-92	50-98

Source: Sloggett (1992) op sit. FAO-UNESCO, 1973; Bos & Nugteren, 1978

Table II.19: Efficiency and Operating Pressure of Various Irrigation Systems

System	Field Efficiency (%)	Operating Pressure (kPa)
Gravity		
Wild Flood	20-50	0
Basin	60-85	0-34
Furrow, Corrugation without return flow	40-70	0-69
with return flow	60-80	35-103
Sprinklers		
Big gun	50-65	827-1138
Centre pivot	60-85	138-621
Side roll	60-80	172-517
Solid set	60-80	172-517
Hand move	55-65	172-517
Drip / Trickle	80-90	35-69

Source: Sloggett (1992)

Table II.20: Production Factors for Triangle Ltd (1995)

Product	Total Output	Ratio per t_{cane}	Sugarcane		Sorghum	
			$t\ ha^{-1}$	$GJ\ ha^{-1}$	$t\ ha^{-1}$	$GJ\ ha^{-1}$
Cane Crushed (t)	2404301	1	115		46	
Bagasse (t) [f]	697247	0.290	33.4	243	13.3	97
Steam (t) [d]	1392848	0.579	66.6	175.2	26.6	70.1
Electricity (GJ) [e]	*368500*	*0.153*	-	*17.6*	-	*7.1*
Coal (t) [f]	-12596	-0.005	-0.6	-16.9	-0.2	-6.7
Steam (t) [d]	-88172	-0.037	-4.2	-11.1	-1.7	-4.4
Electricity (GJ) [e]	*-29665*	*-0.012*	-	*-1.4*	-	*-0.6*
Crystalline Sugar (t)	298133	0.124	14.3		5.7	
'B' Molasses (t) [a]	116547	0.048	5.6		2.2	
'C' Molasses (t)	88821	0.037	4.2		1.7	
'C' Molasses as Sucrose	39969	0.017	1.9		0.8	
Ethanol [b] (t)	19167	0.008	0.9	25.0	0.4	10.0
Stillage [c]	287498	0.120	13.8	4.4	5.5	1.8
ERF [g]	297119	0.124				
Ethanol Only (t) [h]	142477	0.059	6.8	185.5	2.7	74.2

Source: Triangle Ltd. Weekly Factory Performance Summaries: 1997/8. **1 t sorghum stems is assumed to have the same properties as 1 t sugarcane stems**

a) Calculated from 1988 data (88 239 t 'B' molasses produced from $1.82x10^6$ t_{cane}).

b) Calculated from final molasses (i.e. 'C' molasses) is 45% fermentables. Fermentation efficiency is 607 l EtOH per tonne fermentables. Ethanol density is 790 g per litre, calculated from Rosenschein & Hall (1991) data. 21.5 MJ l^{-1}

c) 15 l stillage produced per l EtOH. Stillage density assumed to be 1 kg per litre and contains 0.5% nitrate and 0.5% phosphate. As stillage mixed with irrigation water and used as a fertiliser the energy substitution value of nitrate is 50.1 GJ t^{-1} and phosphate 14.3 GJ t^{-1}.

d) Bagasse energy content 7.6 GJ t^{-1}. Boiler efficiency = 75.7%. Steam energy density 2.88 GJ t^{-1}.

e) Calculated from actual electricity production (368.5 TJ 1997/8, Table 4.25). If calculated assuming an overall conversion efficiency of 11.6% energy in bagasse to electrical energy, total potential electricity production would be 615 TJ.

f) Bagasse energy density is 7.6 GJ t^{-1} @ 50 % moisture. Coal energy density is 28 GJ t^{-1}.

g) ERF (Estimated Recoverable Fermentables = (sucrose + reducing sugars)-losses), assumes 13% BRIX in cane. 2% loss during transport, and a 3% loss during juice extraction.

h) Ethanol produced without any crystalline sugar production, so all ERF directed to ethanol plant Fermentation efficiency as in footnote 'b'. Therefore, potential ethanol production per ha for sugarcane = 8 600 (6.8/0.79) and 3 900 (2.7/0.79) l EtOH ha^{-1} for sorghum.

Table II.21: Energy Consumption at Triangle Ltd. Sugar Mill & Ethanol Plant (Bagasse Energy Equivalent)

Start Crushing:	01-Apr-97		Tonnes Cane Crushed:	2404301	<- 1st Apr to 30th Nov 97	Actual	Bagasse Equiv. GJ
End Date:	29-Dec-97		Actual tc per hour:	368			
No days:	272		% capacity (490tc h-1):	75.16%	Coal Use (t):	12596	332531
No Hours:	6528		Total Bagasse Energy Available:	5329988	Imported Electricity (MWhe):	2986	15887
GJ per MWh:	3.6		Total Energy Consumption (GJ):	5627741	Total Imported Energy (GJ):		**348418**
Boiler Efficiency (Fuel : steam energy):	0.757		Bagasse Energy Surplus (GJ):	50664			
Bagasse Energy Content:	2.217	GJ tc-1 (LHV)	Bagasse surplus (t):	6640			
Bagasse Energy Content:	7.634	GJ tbag-1 (LHV)					

Electrical Power HP Steam Required (assumes: 15.3% electrical efficiency + 1.0% losses + 83.7% energy in exhaust steam)

	MWhe	MWhst	MWhfuel	MWh tc^{-1}	GJ tc^{-1}	%	% OF TOTAL	MWe t_{cane}^{-1}
Power Plant Aux	14598	15552	20544	0.009	0.031	14.13%	1.31%	
Mills	20719	22073	29158	0.012	0.044	20.05%	1.87%	
Factory	22925	24423	32263	0.013	0.048	22.19%	2.06%	
Ethanol Plant	2725	2903	3834	0.002	0.006	2.64%	0.25%	
Sub-Total	**60966**	**64951**	**85800**	**0.036**	**0.128**	**59.01%**	**5.49%**	0.025
Irrigation	35125	37420	49432	0.021	0.074	34.00%	3.16%	
Domestic (village)	7228	7700	10172	0.004	0.015	7.00%	0.65%	
Total	**103318**	**110071**	**145405**	**0.060**	**0.218**	**100.00%**	**9.30%**	0.043
Direct Power								
Mill + Diffuser + Water Pumping		10139	13393	0.006	**0.020**		**0.86%**	
Direct Heat	GJ tc-1	MWhst	MWhfuel	MWh tc^{-1}	GJ tc^{-1}			
Juice Separation	0.598	399252	527414	0.219	**0.790**	37.55%	33.74%	
Sugar Production	0.653	436245	576282	0.240	**0.863**	41.03%	36.86%	
Ethanol Plant	0.129	86140	113792	0.047	**0.170**	8.10%	7.28%	
Losses	0.212	141541	186977	0.078	**0.280**	13.31%	11.96%	
Total					**2.103**	**100.00%**	**89.84%**	