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UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org

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APPROPRIATE TECHNOLOGY FOR THE PRODUCTION OF SUGAR

CANE SUGAR PRODUCTION TECHNIQUES IN DEVELOPING COUNTRIES

Background Paper

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CANE SUGAR PRODUCTION TECHNIQUES
IN DEVELOPING COUNTRIES

by

J. M. Paturau
UNIDO consultant

CONTENTS

(contd.)

SUMMARY

The main physical constraints of cane sugar production are briefly described and the sugar production objectives to ensure socio-economic development are considered.

Alternative methods of production are compared and possible solutions for the more efficient development recommended.

Consideration is given to various technical improvements that would ensure greatly improved results.

Cane sugar production is considered an appropriate production for tropical and semi-tropical Third World countries.

Some of the main socio-economic data of the Mauritius sugar industry are given to serve as guidelines.

1. INTRODUCTION

OUR UNDERSTANDING OF DEVELOPMENT

It is important, at the outset, to try and define what is meant by the term development in the context of this paper, as such definition will condition, to a significant degree, the choice of cane sugar production techniques which will be recommended in the course of this exposition.

We assume that the concept of development, in the context of Third World countries, involves the following key social dimensions, as indicated by A.H. BARCLAY (3):

(i) Reduction in inequalities;

(ii) Decentralisation of economic power;

(iii) Integrated planning to secure balanced growth;

(iv) Mass participation leading to increased self-reliance;

(v) Preservation and enhancement of endogenous cultural traditions.

These social requirements are not likely to be attained, within a reasonable time horizon, unless they are accompanied by the creation of a sufficient number of employment opportunities and a reasonable increase in the gross national product per capita.

To achieve these objectives, we must ensure the growth of planned production, with no significant social and environmental deleterious effects. In a nutshell, this is our understanding of development.

It is hardly necessary to stress the importance of food production in Third World countries, but FIGURE 1 is a useful graphical reminder of this general deficiency situation. The production of sugar, a high energy food, can play an important part, to alleviate this deficit, especially as sugarcane is a very efficient utiliser of solar energy and can produce, under favourable conditions, more than 50 tons of dry matter per hectare per annum, which is about four times as much as most temperate crops.

The cane sugar industry has experienced relatively rapid growth during the past decade in many developing countries and it is considered by many, among other things, to be an instrument for accelerating rural development. A range of operating scales has evolved, ranging from small sugar plants handling one hundred tons of cane per day to large central factories crushing more than 8 000 tons of cane per day. This paper aims at a general appraisal of the factor conditions influencing the choice of capacity. The existing technologies and their unit processes will also be examined to assess their respective merits and indicate, as far as possible, new technological options which would provide a greater degree of flexibility with a view to stimulate the dispersal of industrial activity.

The data utilised is based, mainly, on actual experience derived from cane sugar producing territories which, over the years, have accumulated a substantial amount of technological know-how.

2. THE MAIN CONSTRAINTS OF CANE SUGAR PRODUCTION

It is useful, before considering the socio-economic factors that influence sugar production, to review briefly the main physical constraints that condition such activity.

Sugarcane, a giant member of the grass family, is a typical tropical plant of the genus SACCHARUM which can be sub-divided into 5 species.

One of these species, Saccharum Officinarum, also known as "noble cane" since it is rich in sucrose and relatively poor in fibre, has 80 chromosomes in its somatic cells and is the cane used in sugar production.

(i) SOIL: Sugarcane has proved very adaptable to a wide variety of soil types; it grows on sand and on clay, on limestone and on peat and on a combination of these. A.C. BARNES (4) indicates seven main types of soils where cane has been grown successfully on an industrial scale. G.S. HUSZ (7) recalls that cane should have a well-prepared, well-structured and well-aerated soil profile, to a depth of about 60 cm without compaction or hard-pan in the sub-soil.

Cane can grow on slightly acid as well as on slightly alkaline soils (pH 5 to 8.5), but is only moderately tolerant to salinity (naCl 600 ppm in irrigation water).

(ii) RAINFALL: 20 000 to 25 000 m^3 of water per hectare is generally required in order to obtain very satisfactory cane yields. In many countries an average of 1.5 metre of rainfall during the year, with 2.0 to 2.25 m distributed over the growing period is considered adequate.

With surface irrigation, one should aim at 2.25 to 2.75 m during a growing period of 10 to 12 months.

In Mauritius, with canes reaped annually, overhead irrigation in the sub-humid region, is generally practised per hectare at a rate of 10 mm/hr for about 3 hours at intervals of 10 days.

(iii) TEMPERATURE: Moderately warm temperature are required for propagation. Optimum growth is achieved in temperature between 24^{0} and $30^{0}C$. Temperatures below $21^{0}C$ slows growth, but wide variations occur and canes have been observed growing around $12^{0}C$.

The daily amount of sunshine and the difference between maximum and minimum air temperature has a noticeable influence on the sucrose content of the cane. Eight hours of sunshine per day and temperature fluctuations of $12^{0}C$ should achieve outstanding results.

TABLE 1

METEOROLOGICAL DATA (RAINFALL, TEMPERATURE AND EVAPORATION)

MONTHS	MAURITIUS				NATAL (SOUTH AFRICA)				TUCUMAN (ARGENTINA)			
	RAINFALL (mm)	TEMPERATURE °C		PAN EVAPORATION (mm/day)	RAINFALL (mm)	TEMPERATURE °C		PAN EVAPORATION (mm/day)	RAINFALL (mm)	TEMPERATURE °C		PAN EVAPORATION (mm/day)
		MAX	MIN			MAX	MIN			MAX	MIN	
NOV	96	27.5	19.6	6.1	107	25.2	17.4	5.5	100.5	30.4	16.8	7.6
DEC	180	28.8	21.4	6.2	114	26.6	18.8	6.2	145.6	31.6	18.9	8.1
JAN	280	29.3	22.5	6.0	113	27.2	19.7	6.2	178.3	32.2	19.7	7.0
FEB	281	29.3	22.6	5.8	117	27.4	19.8	5.8	161.8	31.0	19.2	6.3
MAR	307	28.9	22.4	5.0	128	26.9	19.0	5.2	153.1	28.5	17.8	4.8
APR	241	27.9	21.1	4.8	72	25.4	16.7	3.9	63.8	24.9	14.6	4.1
MAY	176	26.3	19.5	4.1	55	24.1	13.8	3.0	26.9	21.4	10.8	3.0
JUN	126	24.8	17.9	3.1	38	22.6	11.4	2.7	0.0	18.5	7.3	2.4
JUL	117	23.9	17.6	2.5	30	23.3	11.0	2.9	0.0	19.4	6.2	3.1
AUG	105	23.7	17.2	1.6	39	22.7	12.1	3.4	9.3	22.2	7.2	4.6
SEP	74	24.6	17.5	2.2	63	23.3	14.1	4.1	15.1	25.8	10.6	6.0
OCT	71	25.7	16.3	3.4	93	24.1	16.0	4.9	59.4	28.2	14.2	6.8
TOTAL	2 054				970				913.0			

TABLE 1 records the meteorological data of three cane growing territories and indicates the normal rainfall and temperature variations during the year.

FIGURE 2 gives a world picture of areas where sugarcane is grown on a commercial scale.

(iv) FERTILIZERS: To schematize a fairly complex problem we can say that, in general, a plant crop of 100 tons will utilize approximately:

70 kg of Nitrogen, 50 Kg of Phosphorus (P_2O_5) and
135 kg of Potassium (K_2O)

In many countries the rate of application of fertilizers per hectare is the following, for ratoon canes:

Standard rates: N:P:K: 150: 75: 75 kg
Heavy rates: N:P:K: 220:110:110 kg

The growth in cane output normally follows a curve of diminishing rate of increase, according to the MITSCHERLICH Law:

$$\frac{dy}{dx} = c(A-y)$$

where A = maximum yield
y = yield produced
x = total of plant nutrients
c = efficiency of the nutrients

The amount of fertilizer to apply per hectare, for maximum economic profits, is governed by the value of the cane on one side and the cost of fertilizer, and of harvesting and transporting the cane on the other.

This is indicated in FIGURE 3, based on conditions presently applying in Mauritius and adapted from D.H. PARISH (25).

The efficient use of fertilizers depends on four main factors:

(i) Crop and soil requirements which govern the quantities of nutrient to be applied;

(ii) Time of application;

(iii) Placement, i.e. on the stool, on the trash, etc;

(iv) Type of carrier, i.e. for phosphates this could be water soluble or insoluble.

Crop and soil requirements can generally be determined by the "crop-log" method advocated by H. CLEMENTS (8) or the less sophisticated "foliar diagnosis" coupled with soil analysis as advocated by P. HALAIS (13).

(v) VARIETIES: Varieties differ in their potential for a given set of soil and climatic conditions and their productive capacity generally deteriorates with age. As a result, most sugar producing countries maintain breeding and selection programmes and many hundreds of thousands new varieties are screened every year, as indicated by R.P. HUMBERT (16). Selection is based on many characteristics including vigour, sucrose tonnage, disease resistance, ratooning ability, suitability to mechanical harvesting, etc. No sugar industry of any consequence can rely on a single cane variety and the importation of successful foreign varieties can only alleviate, but never replace the sine qua non local breeding programme.

(vi) MAJOR PESTS AND DISEASES: The most important pests are rats and five groups of insects:

a) Homoptera, such as the frog hoppers, the sugarcane aphids, and the mealy bugs.

b) Lepidoptera, such as the cane borers and the indian borers.

c) Coleoptera, such as the white grub and the stripe grub.

d) Hymenoptera, such as the cane cutting ant.

e) Insoptera, such as the termites..

Damage to the root system is often caused by Nematodes, especially in poor soils.

The sugarcane diseases are caused by bacteria, fungi and viruses. Among the more important, we can mention:

a) Bacterial diseases such as gum and leaf scald.
b) Fungus diseases such as eye spot, stem rot, pineapple disease.
c) Virus diseases such as mosaic, chlorotic streak, ratoon stunting and Fiji disease.

The above nomenclature, although mentioning only the more important diseases and pests of the sugarcane, is a clear indication that every sugar industry will require some scientific division for the elaboration of suitable protection programmes, as well as continuous applied research (14).

(vii) VARIATION OF SUGAR CONTENT: The sugar content of the cane increases during ripening and it is important, to obtain the maximum amount of sugar, to ensure that the cane is harvested at the right period, neither too early when immature nor too late when it is overripe (cf. R. JULIEN (18). FIGURE 4 gives the average curve of sugar content of canes grown on a 12 months cycle in conditions obtaining in Mauritius. It is evident from this curve that the duration of the harvest should be limited to about 100 days if the maximum amount of sugar is to be obtained. Further reference will be made to that curve when artificial ripeners are considered in Chapter 6. TABLE 2 indicates how the total quantity of sugar would decrease, for a given weight of cane, as the duration of theharvest is lengthened and the loss of revenue that would result. A direct consequence is that the sugar factory must be of adequate capacity to ensure that the canes can be crushed within the optimal period, as any significant extension of the harvest would equate to a loss of sugar.

It should also be pointed out that the cane, once it has been cut, deteriorates fairly rapidly, especially if it has been harvested mechanically and still more if theharvester is of the chopper type.

Good practice is for the cane to reach the factory within 48 hours of its being harvested. With canes from a chopper harvester this timing should be reduced to 24 hours. This deterioration process has been closely studied in recent years and the work of R.A. WOOD (31) and B.T. EAGAN (11) should be studied for a better understanding of the subject.

As a sequel to this constraint of restricted time lag between harvesting and milling, the cane transport system of the sugar factory, and/or the owner growers, should be efficient and should have, at all times, a sufficient number of serviceable vehicles to transport the harvested canes.

(viii) MANPOWER: The production of cane sugar is an agro-industrial process which is relatively labour intensive, especially when the industry has not reached a fairly sophisticated stage of mechanisation. As the alternative methods of sugar production will be considered in Chapter 4, we will simply limit our remarks, at this juncture, to indicate that to produce 1 000 tons of sugarcane one man year is required in Australia, 6½ men year in Natal and 10 men year in Mauritius, due to the relative degree of mechanization reached by these territories. What should be stressed is that any substantial sugar producing industry will require an important labour force - thus to produce 100 000 tons of sugar, some 9 000 men would be required in Third World countries conditions and this labour would, theoretically, have to live within a radius of 7 km, i.e. a population density (if we assume 5 persons per household) of about 300 people per km^2 which is generally higher than what obtains in many rural areas.

TABLE 2

VARIATION OF FINANCIAL RESULTS WITH DURATION OF MILLING CAMPAIGN

DURATION OF CAMPAIGN (DAYS)	AVERAGE SUCROSE CONTENT (SUGAR % CANE)	AVERAGE EXTRACTION (SUGAR % CANE)	SUGAR PRODUCED (TONS)				REVENUES FROM SUGAR SALES (AT $300 PER TON) (US $ M)				OBTAINABLE REVENUES FORSAKEN (US $ M)			
			TONNAGE OF CANE HARVESTED											
			4M	5M	6M	7M	4M	5M	6M	7M	4M	5M	6M	7M
A: PRESENT DATA														
100	13.26	11.54	461 600	577 000	692 400	807 800	138.5	173.1	207.7	242.3	0	0	0	0
123	13.09	11.39	455 600	569 500	683 400	797 300	136.7	170.8	205.0	239.2	1.8	2.3	2.7	3.1
148	12.88	11.21	448 400	560 500	672 600	784 700	134.5	168.2	201.8	235.4	4.0	4.9	5.9	7.9
B: FUTURE DATA (With Utilization of Artificial Ripeners)														
123	13.32	11.59	463 600	579 500	695 400	811 300	139.1	173.9	208.6	243.4	0	0	0	0
148	13.20	11.48	459 200	574 000	688 800	803 600	137.8	172.2	206.6	241.1	1.3	1.7	2.0	2.3

TABLE 3

SUGAR CONSUMPTION

Examples of Sugar Consumption per Caput per Annum

EEC	40-50 kg/year
Eastern Europe	40
USSR	40-50
USA	40-50
Canada	40-50
Japan	40-50
Argentina	40-50
Australia	50
Brazil	40-50
Central America	25
Cuba	50
Dominican Republic	38
India	7
Indonesia	10
Iran	30
Mexico	40-50
Philippines	33
Other Asia	19
South Africa	40

World Average: Approx. 21½ kg/caput/year

TABLE 4

SUGAR PRODUCTION OBJECTIVES

Assume Consumption of Sugar Per Capita Per Annum

Low : 10 kg
Average : 22 kg
High : 40 kg

With 3 Population Hypotheses:

		A	B	C
1.	Population	1 million inhabitants	3 millions	10 millions
2.	Sugar Requirement			
	Low (Sugar Consumption)	10 000 tonnes	30 000	100 000
	Average	22 000 tonnes	66 000	220 000
	High	40 000 tonnes	120 000	400 000
3.	Canes: 9 tons Cane for 1 ton Sugar			
	Low	90 000 tonnes	270 000	900 000
	Average	198 000 tonnes	594 000	1 980 000
	High	360 000 tonnes	1 080 000	3 600 000
4.	Acreage: 80 tons Cane per hectare			
	Low	1 130 hectares	3 380	11 250
	Average	2 500 hectares	7 430	24 750
	High	4 500 hectares	13 500	45 000
5.	Labour Employed: 10 Tonnes of sugar per man year (Alternatively 25 Tonnes of sugar per man year)			
	Low	1 000 (400)	3 000 (1 200)	10 000 (4 000)
	Average	2 200 (880)	6 600 (2 640)	22 000 (8 800)
	High	4 000 (1 600)	12 000 (4 800)	40 000 (16 000)

TABLE 5

CAPACITY OF CENTRAL FACTORY REQUIRED

1. CAPACITY IN TCD FOR A 120 DAYS HARVESTING SEASON

(Alternatively 216 days season)

	A 1 million inhabitants	B 3 millions	C 10 millions
Low (Sugar Consumption)	750 (417) TCD	2 250 (1 250)	7 500 (4 170)
Average	1 650 (917)	4 950 (2 750)	16 500 (9 170)
High	3 000 (1 667)	9 000 (5 000)	30 000 (16 670)

2. Theoretical TCH for 23 Hours per Day Operation

Low	33 (18)	98 (54)	326 (181)
Average	72 (40)	215 (120)	717 (399)
High	130 (72)	391 (217)	1 304 (725)

3. Practical TCH Capacity of Central Factory

Low	35 (20)	100 (60)	350 (200)
Average	75 (40)	220 (120)	2x350 (400)
High	135 (75)	400 (220)	4x350 (2x400)

TABLE 6

LAND CONFIGURATION AND CANE TRANSPORT COST

1. SQUARE CONFIGURATION (L x 1 KM)

	A 1 million inhabitants	B 3 millions	C 10 millions
Low (Sugar Consumption)	3.36 km	5.81 km	10.61 km
Average	5.00	8.62	15.73
High	6.71	11.62	21.21

2. AVERAGE TRANSPORT DISTANCE TO FACTORY (0.39 L)

	A	B	C
Low	1.31 km	2.27 km	4.14 km
Average	1.95	3.36	6.13
High	2.62	4.53	8.27

3. INDEX OF TRANSPORT COST (100 = Index of Transport Cost for 1 Tonne of Cane for 1 km)

(Formula used: Y = 10.52 x + 89.48)

	A	B	C
Low	103.3	113.4	133.0
Average	110.0	124.8	154.0
High	117.0	137.1	176.5

TABLE 7

POPULATION AND TRANSPORTATION OF SUGAR

ITEMS / POPULATION	1 million inhabitants		3 million inhabitants		10 million inhabitants	
DENSITY OF POPULATION (inhabitants/km^2)	150	600	150	600	150	600
AREA INVOLVED (km^2)	6 667	1 667	20 000	5 000	66 667	16 667
RADIUS OF EQUIVALENT CIRCULAR AREA (km)	46.1	23.0	79.8	39.9	145.7	72.8
LENGTH OF AVERAGE RETURN JOURNEY (2/3 R x 2) (km)	61.5	30.7	106.4	53.2	194.3	97.1
TONNAGE TRANSPORTED YEARLY (TON.KM 10^6)						
a) Low Sugar Consumption (10 kg)	0.615	0.307	3.192	1.596	19.430	9.710
b) Average (22 kg)	1.353	0.675	7.022	3.511	42.746	21.362
c) High (40 kg)	2.460	1.228	12.768	6.384	77.720	38.840

3. SUGAR PRODUCTION OBJECTIVES

The average world sugar consumption per head of population is presently around 21½ kg annually. This consumption varies fairly widely from country to country as indicated in TABLE 3. To quantify our objectives of sugar production, we have considered three levels of consumption:

(i) low, at 10 kg per caput per annum;
(ii) average, at 22 kg per caput per annum;
and (iii) high, at 40 kg per caput per annum.

We have also assumed three sizes of population with 1 million, 3 millions and 10 millions inhabitants.

TABLE 4 gives the alternative sugar requirements and also indicates the cane tonnage, the land acreage and the labour employment which would apply.

TABLE 5 gives the capacity of sugar factory required to cope with the tonnage of cane, if we table on a short harvesting season of 120 days or, alternatively, on a long season of 216 effective days of operation.

We now have to consider, being given the land area requirements, what would be the average transport distance for the canes to reach the factory and how this transport cost would vary according to the size of factory contemplated.

This data is summarized in TABLE 6. We have assumed that the land has a square configuration with the factory at the centre and we have used the formula of C.M.R. DRAIJER (10) to determine the distance of transport and the data available in Mauritius for the cost of transport index.

Once the sugar is produced, it has to be transported to suitable marketing points where it is sold to the local population, if we exclude exportation in our initial hypothesis.

TABLE 7 summarizes the possibilities considered with a population density of 150 persons per km^2 and alternatively of 600 persons per km^2. This table indicates that the transport of sugar can prove an important item of cost, the more so with a low density of population, thinly spread over a vast territory.

4. ALTERNATIVE METHODS OF SUGAR PRODUCTION

The question will be considered in two steps, the first dealing with the agricultural production and harvesting of sugarcane and the second concentrating on the processing of the cane into sugar.

a) AGRICULTURE

The agricultural process can be considered under four major aspects namely:

(i) the length of the growing season and crop cycle;
(ii) the method by which the cane is watered;
(iii) the land ownership and labour relationship;
(iv) the harvesting method.

(i) LENGTH OF GROWING SEASON AND CROP CYCLE

In a large number of sugar producing countries the cane is reaped when about 12 months old (16 to 18 months for plant cane), while in a few others, notably Hawaii, the cane is not reaped before it is 22 to 24 months old.

The advantage of this second method is the substantial reduction in preparation, cultivation and planting costs in relation to the quantity of sugar produced. This is counterbalanced, to a certain degree, by the higher costs of irrigation which have to be incurred, to ensure favourable conditions for prolonged growth.

In tropical areas, subject to severe cyclonic occurrences, the question of long cropping would not apply, but in other sectors where climate and soil provide suitable conditions for short as well as long season, production should be decided after a careful evaluation of all economic factors. The cane varieties available will often largely influence the decision, but no hard and fast rule can be given a priori.

The crop cycle, i.e. the number of ratoons that can be successively utilized, is also difficult to determine, unless the more important local factors - especially the varieties cultivated, are taken into consideration after determining how the tonnage of cane produced decreases with successive ratooning, cf. E. HUGOT (15). Some countries have cycles of plant cane + two ratoons, others have a cycle of four ratoons or more.

In Mauritius, the standard practice is for a cycle with seven ratoons. In general, it is prudent, when trying to set up, from scratch, a sugar industry, to table on not more than four ratoons.

(ii) RAINFED OR IRRIGATED CANES

To provide irrigation on cane lands is sometimes a necessity, but it always involves significant cost either as initial capital investment when civil engineering work and water piping reticulation are inevitable or as running cost, especially when pumping is required.

The increased tonnage of cane per hectare which results from irrigation should normally cover the increased costs.

There are regions where the average rainfall is adequate for efficient sugar production and these regions can be regarded as natural sugar areas, very often with fairly low production costs.

However there are also large tracks of tropical countries with relatively dry climate but where surface water is available and which can be changed into very good sugar producing areas once the irrigation infrastructure has been completed. There are a number of examples on the African continent - like Sudan, Ivory Coast and Egypt and more will probably develop in future.

Between these two extremes one can find areas where some irrigation topping up, during the growing period, can help to increase the cane production per hectare.

But whatever the area considered, it is the climatic conditions that dictate the requirements and one cannot speak of alternative choice but rather of the most efficient utilization of the water available whether rainfed or through irrigation.

It is not generally possible to express, with accuracy, the increase in cane tonnage per hectare per month that can be expected when comparing irrigated to rainfed conditions, unless all the local factors are taken into consideration. R. ALPINE and F. DUGUID (2), in two papers considering the viability of sugar production in African countries, give the following norms:

		Small Scale Production		Large Scale Production	
Rainfed	(i)	Long Season	4 Tons Cane/hectare/month	Long Season	5 Tons Cane/hectare/month
	(ii)	Short "	2½ " "	Short "	4 " "
Irrigated	(iii)		n.a.	Long "	10 " "
	(iv)		n.a.	Short "	8 " "

Taking into consideration the average results obtained in Mauritius, in large scale cultivation, it is felt that the rainfed figures

(i) for the short season should be increased from 4 tonnes per hectare per month to 6 T/hectare/month;

(ii) and for the long season from 5 T/hectare/month to 6 T/hectare/month.

For the small scale production, for the rainfed figures, it is felt that it would be more realistic to assume, both for the long and the short seasons average production of 3½ T/hectare/month.

(iii) LAND OWNERSHIP AND LABOUR RELATIONSHIP

The alternative is the following, either the producers own the land or they rent it.

Thus either

a) The land is owned by the planters who can be subdivided into:

   (i) Small planters who cultivate, with the help of their family, their own plot of land;

   (ii) Large planters who cultivate their land, generally with the help of some hired labour;

   (iii) Company which cultivates its land with hired labour.

OR

b) The land is leased by the owners to tenants or "share croppers" who share theproceeds with the owners, generally on the basis of 50% of the crop.

In many cases the company is also the owner of the sugar factory and the planters of that area have to send their cane to be processed at that central factory. Large planters sometimes pool together and own a sugar factory on a cooperative basis. There is also a limited tendency for small planters to form agricultural cooperatives, especially with the advent of mechanization.

The most successful formula appears to be the one exemplified by the Australian sugar industry with medium size planters (average size 34 hectares) who are part owners of a central cooperative factory. The vexed question of allocation of sugar between planters and millers thus does not arise.

The system of share cropping has many drawbacks and should not be recommended. In fact it is slowly disappearing in most sugar industries of the world and, except for a few isolated areas, should not pose a problem in future.

The question of large plantation companies is more difficult to evaluate objectively. Much has been written on "plantation economy" and G. BECKFORD (6) has indicated what he considered the main disadvantages of such economy. He has also indicated the economic development impact of plantation which can be summarized as follows:

a) The opening-up effect which results in the creation of substantial social and overhead capital - schools, clinics, roads, railways, ports, water supply, electricity, telecommunications, etc.

b) The expansion of production and income resulting from plantation activity and its multiplier effect.

c) The contributions to technology through systematic research which generally result in improved varieties, new processing techniques, efficient utilization of by-products, etc.

d) The demonstration effect of plantation production on the output and income of peasant producers.

A balanced evaluation of all pros and cons of plantation economy is not easily arrived at. However, it appears that where there is no foreign ownership of plantations - and thus little "metropolitan" directives - and where the local government has been able, through suitable legislation, to give adequate protection to the small and medium growers, and the labourers in general, the sugar industry and the national economy has prospered, irrespective of the presence of locally owned large scale plantations. The Queensland sugar industry with 11 cooperative sugar factories and 22 proprietary factories is a typical example. To a lesser degree, Mauritius with 2/5 of its cane produced by individual planters and the difference by Company plantations, can also serve as an example of fairly harmonious development with planters receiving 74% of the commercial sugar produced from their cane.

In fact it can be doubted if, without the demonstration effect of these large plantations, the cane sugar industry would have developed at the fairly rapid rate it experienced.

TABLE 8 gives some data how planters and estates cane production have progressed in Mauritius during the last forty years and indicate the synergistic influence of Company plantations and planters.

It goes without saying that large plantations require a significant number of agricultural workers who are not necessarily land owners. Thus if the objective is to ensure that there are only owner growers and no hired agricultural hands, then the large scale plantation cannot be envisaged. It must be pointed out, however, that, unless much freeland is available, a normal increase in the population would force undue parcellisation of the existing plots to maintain the requirement of land ownership for every grower. Agricultural land is generally a scarce commodity and it would appear more realistic to table on some balance between owner growers and agricultural labourers, rather than insist on the exclusive existence of the former only.

Further with the advent of mechanization and automotive transportation the type of jobs offered on large agricultural estates is gradually changing from the unskilled labourer to the semi-skilled or skilled operative and the importance of land ownership would no longer have its previous significance, especially if the estate is the property of a local public company with numerous shareholders.

(iv) HARVESTING METHOD

There are three main possibilities:

(a) The cane is cut and loaded by hand;

(b) The cane is cut by hand and loaded mechanically;

(c) The cane is cut and loaded mechanically.

The availability of labour and its cost seem to be the determining factors in practice.

When the cane is cut and loaded manually, one man day is usually required to cut and load between 2 and 2½ tonnes of cane. The cane supplied to the factory is very clean with little extraneous matter and the cane tops are separated from the millable cane. The cleanly cut whole stick of cane does not deteriorate rapidly and can be crushed with a time lag of 2 to 3 days.

Mechanical loading greatly improves the labour productivity which goes up to 4 to 5 tonnes of cane cut and loaded per man day. The grab loader, with or without push rake, brings in a certain amount of trash with the cane (3 to 5%).

With mechanical harvester and loader, one man day (of 8 hours) can deal with 20 tonnes of cane. The amount of trash and of extraneous matter very with local conditions but come up generally to between 8 and 10% of the net weight of cane. As previously mentioned, the short cane billet (of about 30 cm long) produced by the chopper harvesters deteriorates fairly quickly, especially in a hot and moist climate, and should reach the factory within 24 hours.

TABLE 8

CANE PRODUCTION IN MAURITIUS (MILLION TONNES)

YEAR	ESTATES	PLANTERS	TOTAL
1925	1.054	1.229	2.283
1930	0.988	1.216	2.204
1935	1.317	1.184	2.501
1940	1.506	1.256	2.762
1946	1.421	1.110	2.530
1950	2.254	1.466	3.365
1955	2.500	1.728	4.228
1961	3.031	1.912	4.943
1965	3.619	2.365	5.984
1970	3.181	1.939	5.120
1976	3.977	2.425	6.402

TABLE 9 gives some operating results, observed in USA in 1977, with five different makes of cane harvester. It is reasonable to expect a capacity of 40 TCH and a fuel consumption of 23 litres per hour of diesel oil with the average harvester.

It is difficult to lay down any hard and fast rule, but whenever the cost of cane cutting and loading reaches US $2 per tonne, there is an economic incentive to consider mechanization, starting with loading. Mechanical harvesting is a more complex operation which requires adequate land preparation and is not adapted to smallish fields. It should be regarded as the second stage of sugarcane development, once the industry is well established and the standard of living has risen, bringing the GNP per caput to about $500.

b) FACTORY

A sugar factory can be:

(i) A family workshop, producing a very primitive type of sugar, generally termed "GUR", as illustrated schematically in FIGURE 5.

(ii) A small scale OPEN PAN sugar factory producing brown sugar, generally termed "KHANDSARI", and illustrated in FIGURE 6. The capacity is usually between 100 and 200 TCD.

(iii) A large scale VACCUM PAN sugar factory producing raw or plantation white sugar, and illustrated in FIGURE 7. The capacity is usually between 100 and 200 TCH 8i.e. 2 400 to 4 800 TCD).

Although gur is produced in very large quantities in India - probably some 7 million tonnes yearly, yet it is not felt that such a primitive method of sugar manufacture has much to commend itself for the agro-industrial development of a country. The alternative to be considered will thus be between the small scale OPEN PAN and the large scale VACUUM PAN methods of production. The UNEP/UNIDO Seminar held in NAIROBI (Kenya) in April 1977, considered this question in depth. Some of the papers indicated that from the social and environmental point of view the small scale model of production appeared preferable. Thus R. ALPINE (1) when measuring social profitability on the basis of Net Present Value per tonne of sugar per annum arrived at $768 for small scale production of 100 TCD and $541 for large scale production of 100 TCH.

However, it is useful to point out that, when a sugar estate has reached its normal development, the net surplus (i.e. revenue - operating cost) per tonne of cane is $3.92 in small scale production against $10.82 for large scale production.

TABLE 10 gives some data of these comparative operating costs and revenue extracted from the papers of R. ALPINE and F. DUGUID (2) and it must be stressed that the net surplus per hectare is about $179 in the small scale production while it is about $649 in the large scale production.

Further, when detailed consideration is given to the equipment required for a 100 TCD OPEN PAN sugar factory (cf. FIGURE 6) and this is compared with the equipment of a 100 TCH Vaccum Pan factory (cf. FIGURE 7), it is by no means obvious that the equipment for the large scale production is in a class, of complexity and sophistication, far above that required for small scale production. Vacuum Pans, Juice Heaters, Evaporators and Barometric Condensers are fairly straightforward pieces of equipment, mainly of fabricated steel, and with hardly any moving parts. Once a standard design and construction drawing has been obtained, it is relatively easy to extrapolate for varying capacities and the construction of such items should be within the reach of fair size workshops of many developing countries - (cf. the successful experience of India, Egypt, Mauritius, West Indies, etc.)

TABLE 9

PERFORMANCE OF FIVE DIFFERENT MAKES OF MECHANICAL HARVESTERS
(USA, JUNE 1977)

MANUFACTURER	AVERAGE OPERATING HOURS PER MONTH	TONNES OF CANE HARVESTED PER HOUR	TONNES OF CANE PER LITRE OF FUEL	LITRES PER HOUR
A	145	50.3	1.56	32.2
B	104	26.8	1.15	23.3
C	202	40.5	1.78	22.8
D	384	37.2	2.13	17.5
E	431	37.4	1.33	28.1

TABLE 10

COMPARATIVE PRODUCTION COST OF SUGAR

(Data extracted mainly from the papers by R. ALPINE and F. DUGUID)

ITEMS	SMALL SCALE OPEN PAN (100 TCD)		LARGE SCALE VACUUM PAN (100 TCH)	
A. LONG SEASON, RAINFED	202 days; 443 hectares		216 days; 8640 hectares	
	100x202 = 20 200 TC		100x24x216 = 518 400 TC	
Agricultural Operating Cost	$168 500 or $8.341 per TC		$5.7m or $10.995 per TC	
Factory Operating Cost	138 000	6.832	3.3	6.366
Administrative Operating Cost	n.a.	n.a.	2.16	4.167
Total	$306 500	$15.173	$11.16m	$21.528
Revenue	$385 700	$19.094	$16.77	$32.350
Net Surplus	$ 79 200	$ 3.921	$ 5.61	$10.822
Net Surplus per hectare	79 200÷443 i.e.$178.78		5.61÷8 640 i.e.$649.31	
Net Surplus per hectare for agriculture only	$\frac{108\ 500 \times 79\ 200}{306\ 500 \times 443}$ = $98.29		$\frac{5.9 \times 5\ 610\ 000}{9.0 \times 8\ 640}$ = $411.23	
B. SHORT SEASON, RAINFED			(USING MAURITIUS ACTUAL RESULTS)	
	112 days; 406 hectares		120 days, 3 671 hectares	
	112x100 = 11 200 TC		100x24x120 = 288 000 TC	
Agriculture Operating Cost	$146 700 or $13.098 per TC		n.a.	$22.90 per TC
Factory Operating Cost	99 500	8.884	n.a.	7.36 per TC
Administrative Operating Cost	n.a.	n.a.	n.a.	n.a.
Total	246 200	21.982		30.26
Revenue	214 200	19.125	Revenue 39.72	
Net Surplus	(-32 000)	(-2.857)	Net Surplus 9.48	
Net Surplus per hectare	(-78.81)		Net Surplus per hectare $742.23	

When reviewing certain new techniques, in Chapter 6, it will be indicated that the modern large scale sugar factory will tend towards simplification with the adoption of continuous processes in all departments. Therefore it appears questionable whether the choice of small scale production is in fact the best socio-economic avenue of development and whether this supposedly "appropriate" technology would not in fact slow down the possible growth of the country while accustoming its inhabitants to a mediocre technology with substantial sugar losses and with few prospects of improvements.

With the rapid growth of education in all developing countries and the opening up to new ideas with the phenomenal expansion of communications, it would be dangerous to underestimate the possibility of adaptation of Third World nations to moderately advanced technology and it would seem that the production of sugar by vacuum pan technique falls well within such possibility.

5. POSSIBLE SOLUTIONS

The recent development of sugar industry in Third World countries has generally followed the large plantation model with a modern vacuum pan central fact ry, as exemplified in Ivory Coast, in Sudan and in Kenya. The creation of a class of medium size planters or alternatively of small size planters pooling their resources within cooperatives, appears to be the main requirement for the socio-economic development of the country or of the region. It would seem preferable for the factory to be a cooperative, owned by all planters, and run by local technicians and managers of the private sector. During the initial years of construction and start up period, some foreign specialists would be required; but they would have local counterparts, having received preliminary training in advanced sugar producing countries, and who will take over after three or four years.

The creation of a research agronomic and technological division, with adequate extension services, is essential to ensure the progress of the newly developed local sugar industry. One should not minimise the beneficial demonstration effect of a few local large planters, who would set the standard of efficient technology and management.

The public sector should not be concerned with the day to day running of the sugar industry. It would be responsible for the initial allocation of lands and would ensure the minimal infrastructure necessary - roads, bridges, electricity, water, etc. It should also promulgate the necessary wages regulations so that labourers and operatives, where employed, should obtain adequate renumerations.

When the problem is to further develop an existing sugar industry, it is prudent not to try and change overnight, what has been painstakingly established over many years. The Australian sugar industry is a good example of efficient accommodation with a mixture of proprietary and cooperative establishments. Where foreign assets are predominant, then the gradual buying up of such assets by local interest should be the objective, bearing in mind however that the foreign specialists should be replaced by equally qualified local technicians, if the industry is not to be jeopardised.

6. TECHNOLOGICAL ADVANCES THAT SHOULD BE CONSIDERED

It is proposed to review, in the following pages, a number of possible improvements that would have an important bearing on the economic development of the sugar industry and thus help Third World countries to progress towards their socio-economic objectives, as defined in Chapter 1.

a) MORE EFFICIENT USE OF NITROGEN AS FERTILIZER

The paramount importance of nitrogen on cane yeild, and also the fact that it is the most expensive nutrient, dictates thenecessity for detailed studies for its fate after application, for a better understanding of volatization, leaching and nitrification losses which are, in practice, very substantial.

The efficiency of nitrogen fertilization leaves much to be desired as the bulk of applied nitrogen, probably more than 50%, is lost to the plant. Various lines of research appear desirable such as the use of the isotope N^{15}, the action of nitrification inhibitors, the subsoil application of ammonia, the biological production of nitrogen by bacteria living in or near the root system, etc. This is an important area where industrialised nations can help Third World countries, while at the same time helping their own agriculture.

b) UTILIZATION OF ARTIFICIAL RIPENERS

The use of chemical ripeners to increase the sucrose content of canes, early in the harvest season, has been studied in recent years. The economic benefits that can result from successful application of these compounds are significant, as indicated in FIGURE 4 and TABLE 2, and include avoidance of late harvest when yields tend to be lower and labour less efficient, (19).

The response to ripeners now used commercially has been shown to depend on variety - those with high sucrose content respond better, time of application and the interval between application and harvest. The maximum response occurs about 8 weeks after application and the dosage is between 3 and 4 kg per hectare for one of the more widely used ripener. The compound is most effectively applied early in the crop season when canes are immature. Poor ratooning has occurred in the subsequent crop in some trials, and this is a potential drawback that should be closely studied.

Generally speaking the use of chemical ripeners is still in its infancy, but it is showing sufficient promise for a more systematic usage to be envisaged and significant results can be expected.

c) DIFFERENTIAL SPACING TO ALLOW INTER ROW CULTIVATION

The spacing between rows of cane vary from one country to the other but is generally of the order of 1.30 to 1.50 metre. It has been demonstrated experimentally that with alternate inter rows of 1.00 metre, 2.00 metre, 1.00 metre, 2.00 metre, etc., the total yield of sugar per hectare can remain the same as with the constant 1.50 metre inter row. c.f. MSIRI (24).

The great advantage, especially for countries having long ratooning cycles and thus few fallow periods preceding replanting, is that the large interrow of 2.00 metre can be utilized,generally up to the 4th ratoon, for growing other crops like groundnuts, potatoes, soja, dwarf maize, etc.

In practice about 30% of the land under cane, for a crop cycle of 7 ratoons, can be used for interrow cropping. For a shorter crop cycle of say 3 ratoons, the area utilizable goes up to 50%.

This is an important asset for countries where arable land is in short supply. Further it enables the cane planters to have an increased income from their acreage and allows a more uniform utilization of their labour, since crops like potatoes, maize, groundnuts, etc, can generally be reaped during the inter-harvest season when labour is not so fully utilized as during sugar crop time.

d) IMPROVED MIXING EFFICIENCY OF THE MILLING PLANT

The efficiency of the standard three roller mill has hardly improved in the last fifty years; what has improved is the rate of throughput for a given mill size which has increased almost fivefold during these five decades.

In a modern milling train the first mill is a mechanical separator of juice from cane, and the other succeeding mills (generally 4 to 5 in number) or a diffuser, represent a multi-stage countercurrent leaching system to extract part of the solute remaining after the first mill extraction. The extraction efficiency of a good milling train can be assumed to reach 96%. But when we consider the efficiency of each mill separately, we obtain the following results:

MILLS	1	2	3	4	5	
EXTRACTION	70%	15%	6%	3%	2%	TOTAL: 96%

The relatively poor extraction of the last four mills is due mainly to the inefficient mixing of the solvent with the solute impregnated bagasse. This has been pointed out by DOWES DEKKEK (9) in 1959, by BUCHANAN (5) in 1965 and again by RIVIERE (28) in 1976. Rivière explains in detail, with the help of a graphical solution of solid-liquid extraction process, known as the PONCHONSAVARIT diagram, how 2 mills could theoretically achieve a 96% extraction, if the efficiency of mixing was improved. It is highly desirable for research technologists of the sugar industry to pay much more attention to this requirement which could have very important economic implications.

A significant reduction of power used by the milling train would mean a commensurate reduction in live steam consumption and hence a substantial saving of bagasse which would then be available for other purposes of greater economic value than its unprocessed use as fuel - cf. FIGURE 10 which gives a general idea of possible by-products upgrading in the cane sugar industry.

The work done in REUNION ISLAND by Rivière and Langreney, to prevent air reabsorption by the bagasse issuing from the first and succeeding mills, is a step in the right direction to ensure more intimate mixing. The device is almost elementary, since it simply submerges the issuing bagasse in a bath of inhibition juice. But it is said to have increased extraction, which is a much needed improvement.

The time seems ripe for a major advance in milling efficiency, but progress will not be achieved unless further research is performed along the right line.

e) REDUCTION OF HEAT LOSSES

Among the heat losses of a sugar factory the following are fairly important and occur:

(i) In the flue gases escaping up the chimney stack;

(ii) In the warm water issuing from the barometric condensers.

These two losses can be appreciably reduced in the following way:

(i) Mixed juice is sprayed in the chimney and is heated up by the escaping flue gases. A double result is thus obtained since the juice spray abates the nuisance of flyash and at the same time reduces the final temperature of the flue gases from say 200°C to about 150°C, and hence the chimney stack losses. Theheated juice (at about 65°C) is screened and allowed to settle in a small clarifier and then follows the normal process of juice treatment.

(ii) Alternatively cold mixed juice can be used to replace cooling water in the barometric condenser of the evaporation station. The condenser plays the part of an efficient juice heater as indicated by PATURAU & STAUB (26) and the usual condenser cooling water losses are thus eliminated.

(f) ECONOMY OF EXHAUST STEAM

FIGURE 9 gives a good indication how the evaporator, juice heater and pans arrangement, within a sugar factory, can be improved to reduce, very substantially, the requirement of exhaust (low pressure) steam.

To produce exhaust steam we need to generate live steam, i.e. to burn bagasse. Hence a saving in exhaust steam means an equivalent saving in bagasse.

With a cane having 13% fibre, a re-arrangement of the boiling house, as indicated in FIGURE 9, can equate to an exhaust steam consumption of 34% cane and to 39% surplus bagasse, i.e. a surplus of 51 kg of fibre per tonne of cane.

This is a major improvement and generally it is well worth the capital expenditure required to acquire one supplementary evaporator vessel and two juice heaters. It is sometimes difficult to limit the live steam consumption of a sugar factory to 34% cane, but bearing in mind the remarks in d) above, this should prove easier to achieve in future.

g) CONTINUOUS VACUUM PANS

The general trend of improvements in the sugar industry has often evolved from the replacement of a batch process by a continuous one. Thus the industry has moved from filter presses to rotary filters, from decanters to clarifiers, from batch centrifugals to continuous ones, etc.

The advent of the continuous vacuum pan is now more than a promise and quite a few continuous pans are presently utilized on an industrial scale in the cane sugar industry. This allows some simplification in the boiling department with less equipment, less supervisory labour and a much more uniform and efficient utilization of exhaust steam which will improve the steam balance throughout the factory.

The main difficulty with continuous pans is that they have a tendency to produce final sugar with a relatively wide spread of grain sizes. But there are good reasons to believe that this drawback will be eliminated within the next few years.

h) PRODUCTION OF ELECTRICITY

The average raw sugar factory should normally have a surplus of electrical power which it can sell during the cropping season. If the national grid reticulation is well developed and can easily be linked up to the factory, this can represent an important number of units of cheap electricity made available to the general public, while providing some revenue to the sugar factory. Theoretically, with medium pressure boilers (60kg/cm^2) and pass-out/condensing turbo-alternators, a modern sugar factory, should be able to produce a maximum surplus of 50 Kwh per tonne of cane, (425 Kwh per T. of sugar), which is saleable to the grid. Many sugar producing countries, especially the smaller island territories, have developed this possibility, Hawaii and Mauritius being typical examples.

Hawaii, from its bagasse, produced, in 1975, for export to the grid, 164 m. of Kwh (i.e. about 160 Kwh per tonne of sugar) which brought in an income of Us $2 469 500 (i.e. $0.0121 per Kwh).

Mauritius, from its bagasse, produced, in 1976, for export to the grid, 25 m. of units (i.e. about 36 Kwh/t of sugar) and received therefrom an income of US $332 167 (i.e. $0.0132 per Kwh). The range of units produced in Mauritius per tonne of sugar varies, from factory to factory, between 96 Kwh and 4 Kwh which indicates that there is much room for further development.

It must be pointed out that using bagasse as fuel to produce electricity is a simple process fairly easily implemented; but it does not give a very high value up-grading to the bagasse. Thus one tonne of bone dry bagasse can produce about 900 Kwh of electricity and if sold at $0.02 per unit, this will equate to a revenue of $900×0.02 = $18. While if the bagasse is transformed into bleached pulp (worth say $370 per tonne) then one tonne of bone dry bagasse could produce about 350 kg of bleached pulp worth $130.

It is only fair to indicate, however, that capital intensity and technical know-how generally increase with the complexity of the process and that maximisation of profits depends more often on advantageous local conditions than on process sophistication. Thus, for a start, the sale of electricity produced from bagasse may be a bird in the hand rather than the two in the bush represented by the transformation of bagasse into bleached pulp.

(i) PRODUCTION OF ETHANOL (ETHYL ALCOHOL)

There is no necessity to describe the well-known fermentation process by which ethyl alcohol is produced from molasses. What is important, in the present juncture, is the high price of petroleum products and especially motorcar gasoline which can be theoretically replaced by absolute ethyl alcohol (200 proof) in a suitably modified internal combustion engine. Research has reached an advanced stage at the plant of a large German car manufacturer and Brazil has an ambitious programme of alcohol production, initially for a mixture of 15:85, alcohol/gasoline, but finally for the sole use of alcohol as motorcar fuel.

One litre of absolute alcohol could replace 0.73 litre of gasoline and if gasoline is sold for about US $0.40 per litre, this would put the equivalent selling cost of alcohol at US $0.30 per litre.

Under reasonably favourable conditions, ethanol can be produced at that price provided molasses is available at about $20 per tonne.

It is difficult,without a full knowledge of all local factors, to recommend the production of absolute alcohol. But in view of the foreign exchange required for petroleum importations, it would be prudent for a number of Third World countries, at least to investigate the possibility to utilise alcohol as motor fuel, as an insurance for the future if gasoline increases in price or its supply becomes difficult.

j) UTILIZATION OF CANE TOPS

Cane tops represent, when fresh, (at 28% dry matter) some 40% of the weight of canes sent to the sugar mills. Thus for every 100 Tonnes of canes crushed in the factory, some 40 Tonnes of cane tops remain available in the cane fields and can be used as animal feed.

Fresh cane tops have a metabolizable energy of about 680 kcal or 2.8 MJ per kg of dry matter. With the addition of some 5% by weight of molasses, it can play an important part in the production of bovine meat.

The construction of feedlots adjacent to sugar mills has simplified the handling and transport of such feeds and the concentration of animals has rendered feasible the conversion of organic waste into methane and fertilizer. Methane can be used as fuel for household cooking or in modified stationary engines to produce electricity.

FIGURE 11 gives some indication how a thorough utilization of by-products of the sugar industry can substantially improve the revenues of this industry through a planned programme of diversification. It is evident that the example chosen may not be applicable in toto to every sugar industry, but alternative choice of industries are available and what should be stressed is that the rational utilization of by-products can increase the turnover of a sugar estate by almost 50%.

k) UTILIZATION OF SUGAR MACHINERY DURING INTERCROP

One of the great drawbacks of a sugar factory is that the expensive items of machinery it contains are only utilized for about six months of the year. Little has been published on possible alternative use for such machinery and for a fuller utilization of the technical personnel of the factory. PATURAU (27) has indicated one or two possibilities in a general review of the question, but more in depth research would be required to achieve some efficient utilization, on a year round basis, of sugar factories.

If a large scale alcohol industry is developed then the evaporation of distillery stillage may be undertaken utilising the Evaporator and Steam Generating Stations of the sugar factory. Steam could be generated, either with surplus bagasse or fuel oil; the medium pressure steam would produce electricity via a back pressure turbo-alternator and the issuing exhaust steam would be used in the Quadruple Effects of the evaporation station to concentrate the stillage from 8% to 60% of solids. The syrup can be mixed with cane tops, bagasse pith, etc., to produce a compounded animal feedstuff.

A distillery having a yearly capacity of 120 000 hectolitres would produce 1 850 000 hectolitres of stillage (i.e. 185 000 tonnes). To evaporate this stillage in Quadruple Effect would require about 41 000 tonnes of exhaust steam.

If we assume that the utilisable time during the intercrop is limited to 2 400 hours (i.e. about 4 working months); then the exhaust steam required per hour would be about 17 tonnes, which is well within the possibility of a 100 TCH factory.

If we assume that the turbo-alternator will have a steam rate of 10 kg per Kwh, then the total units of electricity generated during the 4 months will be approximately $\frac{17\ 000}{10} \times 2\ 400 = 4\ 080\ 000$ Kwh, say 4 million units.

CONCLUSION

Cane sugar with its efficient photosynthesis system and its requirement of fairly intense sunlight is an appropriate production for tropical and semi-tropical Third World countries.

It can progressively transform a peasant economy into an agro-industrial one provided the technological know-how is made available at the rate which can be fairly easily absorbed by the rural population.

The public sector has an important part to play to guarantee, in the initial stages, the peasants against too great an economic risk which generally accompany the implementation of new techniques.

The fear of an economic risk is a paramount factor, in the inertia against change, of rural community. And this should be understood and countered by appropriate measures to achieve reasonable development success.

The demonstrative effect of large planters to show what is realisable, with maximum efficiency within a reasonable time, is also an important factor.

Finally the industry must drastically limit foreign influence and see to it that the development benefits the whole nation through the producers and not just a few absentee land owners.

Although theoretical studies can serve as pointers to the type of appropriate technologies best adapted to the development envisaged, yet practical data obtained from operating sugar factories are most important to verify whether some of the theoretical assumptions are not too optimistic.

With this aim in view, Appendix I, II and III give average labour requirement and production cost in Mauritius, in 1976, for the whole sugar industry; and this data should prove useful to ensure realistic extrapolations.

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APPENDIX I

MAURITIUS 1976 CROP RESULTS

(N.B. The numbers between brackets refer to the minimum and maximum)

1. GENERAL CROP DATA

Number of working days: Average 149 days (115-182)

Number of crushing days: Average 144 days (113-175)

Sugar estates canes: Total 3 977 578 tonnes

Average per factory: 189 408 tonnes (66 158-495 278)

Planters canes: Total 2 424 699 tonnes

Average per factory: 115 462 tonnes (42 768-322 364)

Island total canes: 6 402 777 tonnes

Average per factory: 304 894 tonnes (162 824-818 007)

Total sugar produced: 689 932 tonnes

Average per factory: 32 854 tonnes (16 688-85 851)

Average daily crushing time: 18.97 hrs (16.62-22.20)

Average crushing rate TCH: 111.3 (55.1-238.8) tonne cane hour

Total man days (whole year): 11 954 265

Average daily attendance: 41 331 persons

2. LABOUR REQUIREMENTS: Cultivated area: 49 634 hectares

A. CULTIVATION: Total man days: 8 204 974

Average per hectare: 165.31 man days per hectare

(i)	Planting 752 109 man days,	= 15.15 man days per hectare
(ii)	Clearing 2 387 179 man days,	= 48.10 man days per hectare
(iii)	Irrigation 270 879 man days,	= 5.46 man days per hectare
(iv)	Thrashing 718 493 man days,	= 14.48 man days per hectare
(v)	Cutting & Loading 2 230 898,	= 44.95 man days per hectare
(vi)	Relieving straw 517 414,	= 10.42 man days per hectare
(vii)	Application of fertilizers 151 827,	= 3.06 man days per hectare

APPENDIX I (contd.)

(viii) Earthing up 96 494, = 1.94 man days per hectare

(ix) Repairs to roads, bridges & canals 350 831, = 7.07 man days per hectare

(x) Other agricultural work 426 816, = 8.60 man days per hectare

Worker per hectare per day : 0.57 average

B. FACTORY:

Sugar produced: 689 932 tonnes

Processing: 501 266 man days, 0.727 man days/tonne

Sundries: 755 796 man days, 1.095 man days/tonne

Total: 1 257 062 man days, 1.822 man days/tonne

C. ESTATE SUNDRIES:

Food Crops	270 425 man days
Other activities	437 701 man days
General expenses	677 908 man days
Non-recurrent	291 856 man days
Mechanical Transport	814 339 man days
	2 492 229 man days

D. GRAND TOTAL:

8 204 974 + 1 257 062 + 2 492 229 = 11 954 265 man days to produce 2 424 699 tonnes of canes and process 689 932 tonnes of sugar.

APPENDIX II

MAURITIUS CANE PRODUCTION COST SUMMARY (1976) IN US DOLLARS

	Per Ton Cane	Per Ton Sugar	Per Hectare
A. DIRECT EXPENSES			
(a) (varying with area cultivated)			
Clearing, Ploughing and Planting	3.27	29.83	263.99
Fertilization	1.73	15.78	139.66
Weeding & Trashing	2.37	21.62	191.33
Irrigation	0.53	4.83	42.74
Overseers Retribution	0.67	6.11	54.09
Transport of Labourers & Supplies	0.90	8.21	72.66
Total (a)	9.47	86.38	764.47
(b) (varying with tonnage harvested)			
Cutting and Loading	2.22	20.25	179.21
Transport of Canes	1.82	16.60	146.91
Total (b)	4.04	36.85	326.12
TOTAL DIRECT EXPENSES	13.51	123.23	1 090.59

APPENDIX II (contd.)

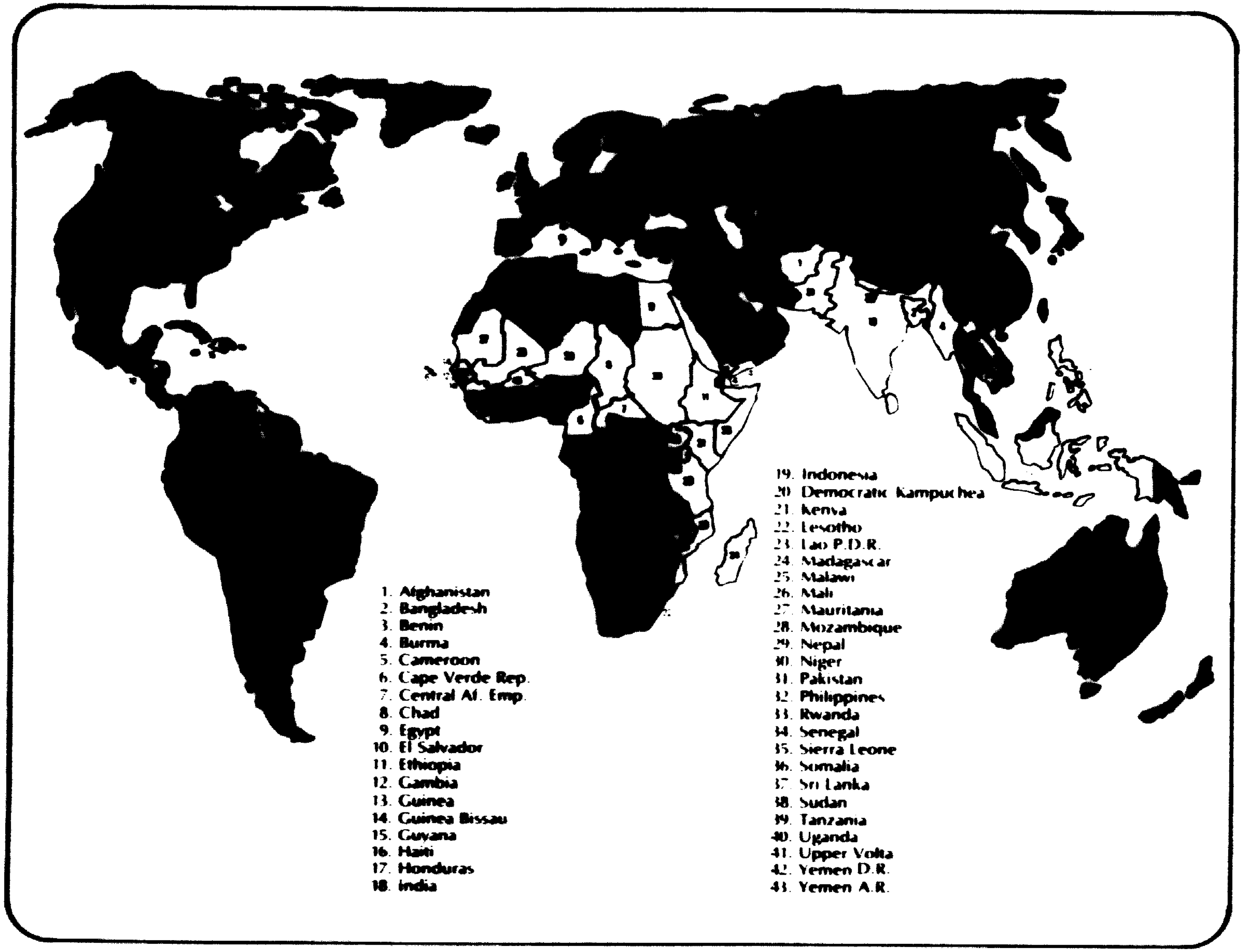
	Per Ton Cane	Per Ton Sugar	Per Hectare
B. OVERHEADS			
Salaries (inclusive of pensions & bonuses)	4.22	38.50	340.72
Repairs & maintenance, tools and stores and sundry expenses	1.45	13.24	117.17
Administration and welfare	1.84	16.79	148.59
Depreciation (excluding transport equipment)	0.20	1.82	16.11
Sugar insurance premium (gross)	1.46	13.32	117.88
Interest payable	0.24	2.19	19.38
TOTAL OVERHEADS	9.39	85.86	759.85
cane production cost	22.90	209.09	1 850.44

APPENDIX III

MAURITIUS SUGAR MILLING COST SUMMARY (1976) IN US DOLLARS

	Per Tonne Cane	Per Tonne Sugar
DIRECT EXPENSES		
Milling and Processing Labour wages	0.49	4.53
Lubricants, Fuel, Chemicals & Stores	0.19	1.76
Bagging, Loading, Bags & Thread	0.27	2.50
TOTAL DIRECT EXPENSES	0.95	8.79
OVERHEADS		
Salaries (inclusive of pensions & bonuses)	0.88	8.14
Repairs and maintenance	0.94	8.69
Sundry expenses & insurance	0.27	2.50
Transport and weighbridges	0.32	2.96
Administration, welfare & services to planters	1.79	16.56
Depreciation (excluding transport & weighing equipment)	1.60	14.80
Sugar insurance premium (gross)	0.53	4.90
Interest payable	0.08	0.74
TOTAL OVERHEADS	6.41	59.29
COST OF SUGAR EX-FACTORY	7.36	68.08
Transport cost to export warehouse	0.27	2.50
COST OF SUGAR AT WAREHOUSE	7.63	70.58
N.B.: TOTAL PRODUCTION COST OF SUGAR (AGRICULTURE + PROCESSING)	$30.53	$279.87

FOOD PRIORITY COUNTRIES



(Adapted from OECD OBSERVER - No. 91 MARCH 1978)

FIGURE 1

MAIN CANE SUGAR PRODUCING COUNTRIES

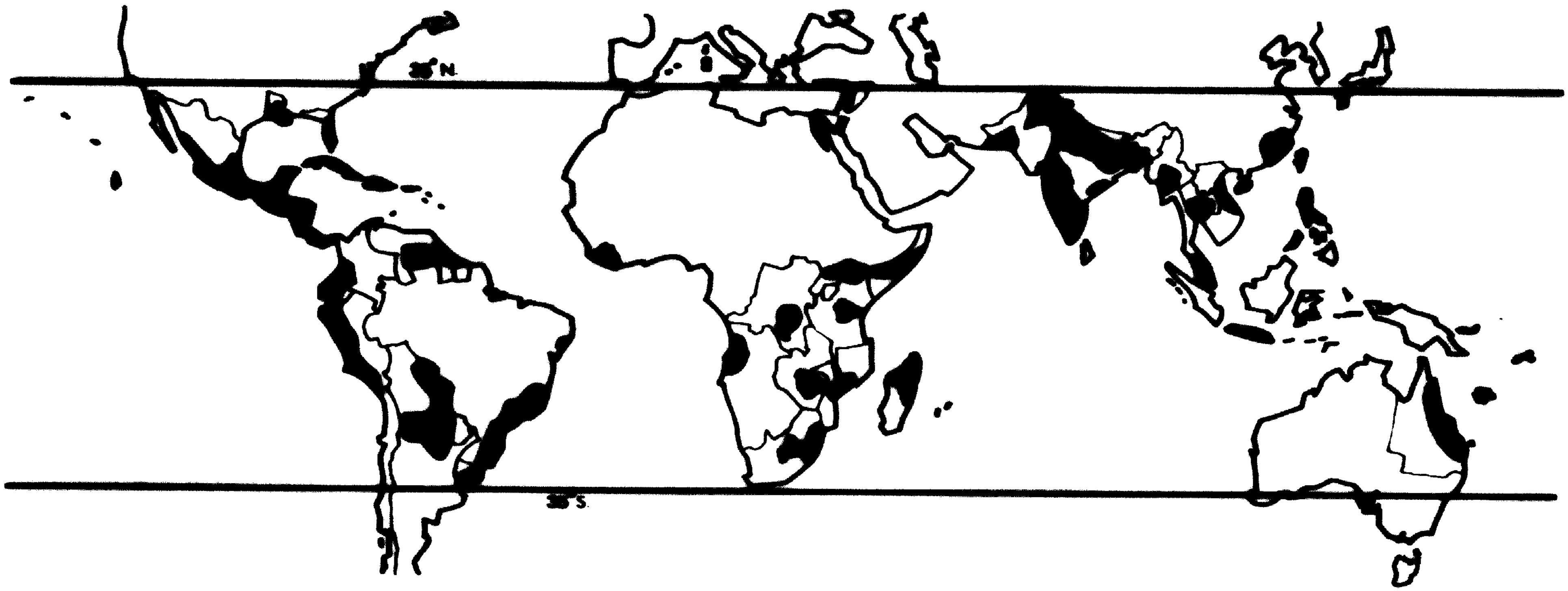


FIGURE 2

CHARACTERISTIC CURVE OF RATIONAL FERTILIZER UTILIZATION

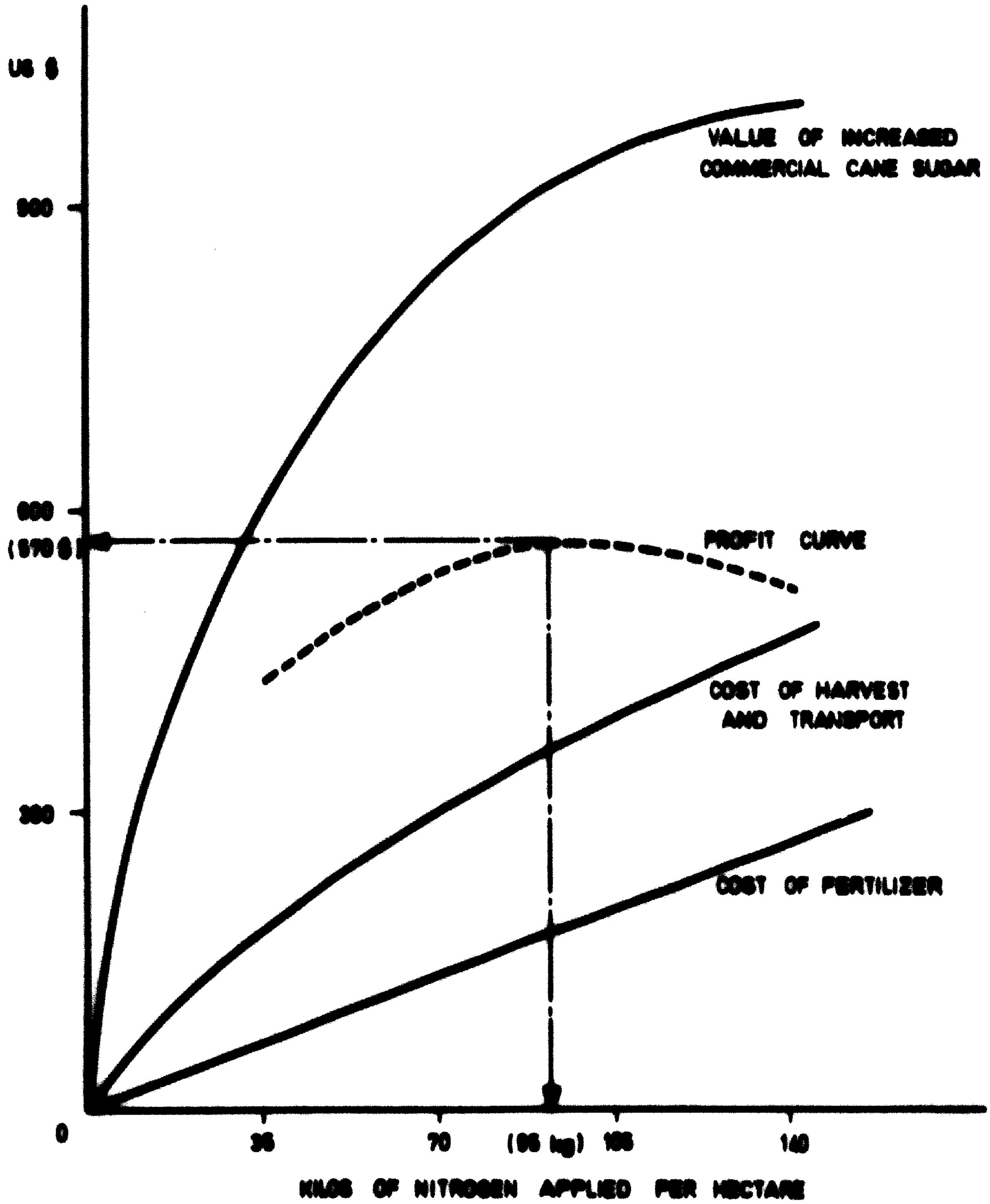
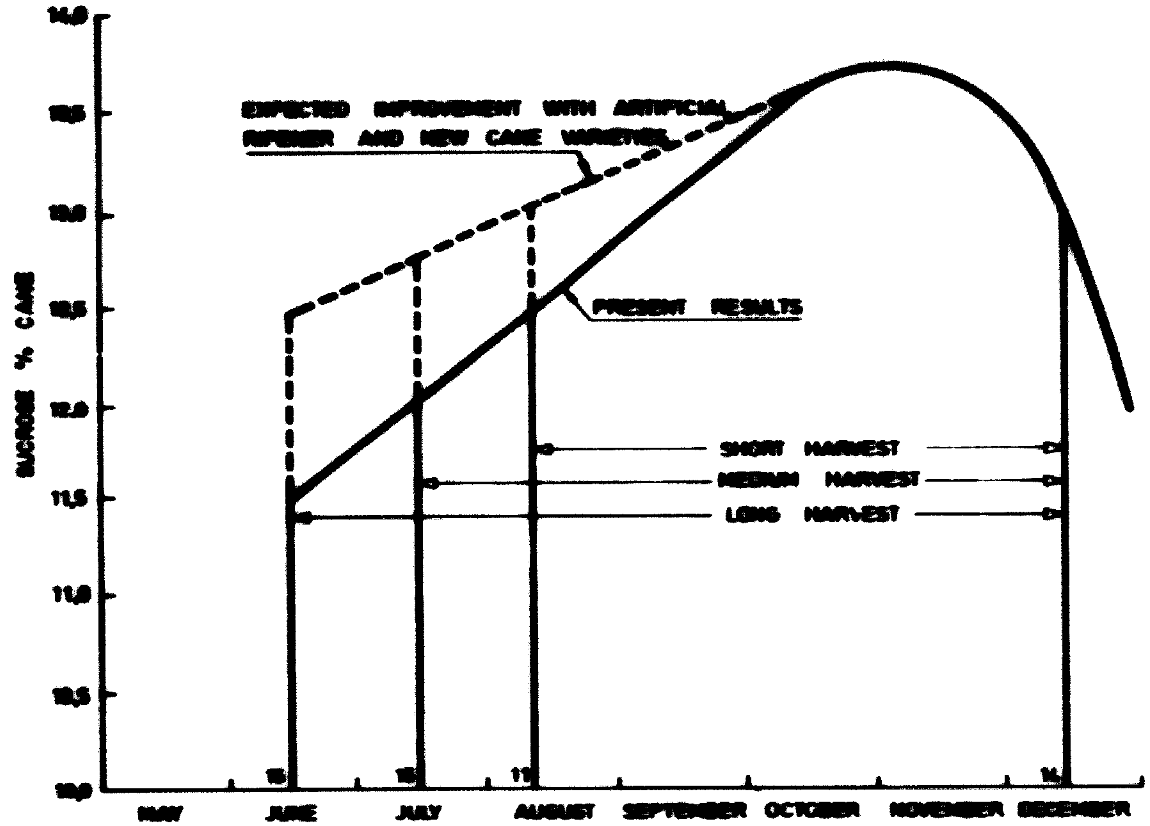


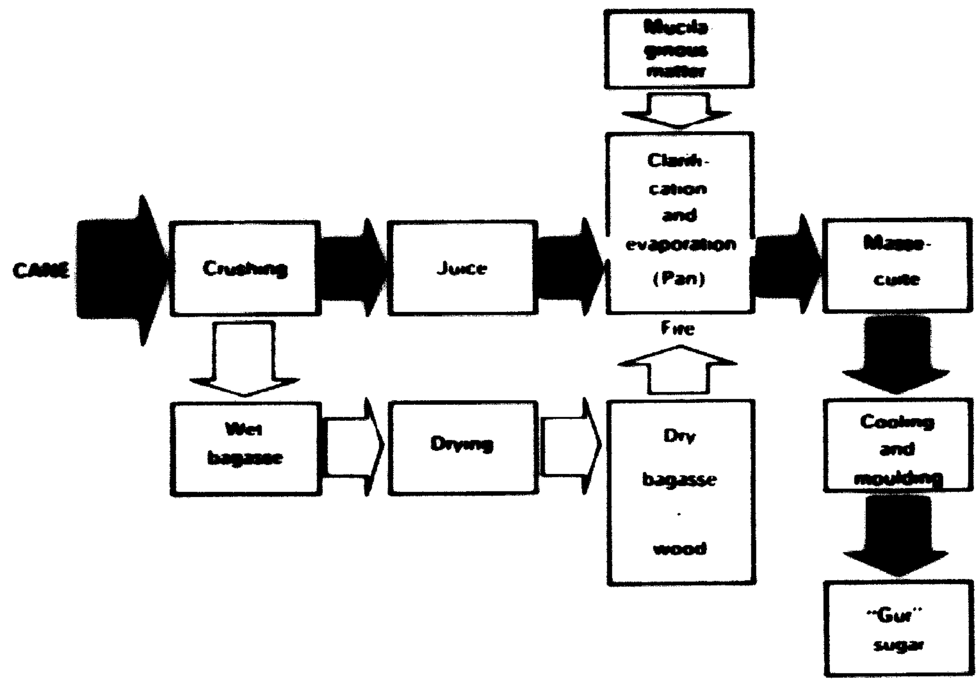
FIGURE 3



VARIATION OF THE SUGAR CONTENT OF THE CANE DURING HARVEST

FIGURE 4

FAMILY WORKSHOP FOR GUR PRODUCTION



(Adapted from Techniques & Development - No. 4 - November 1972)

FIGURE 5

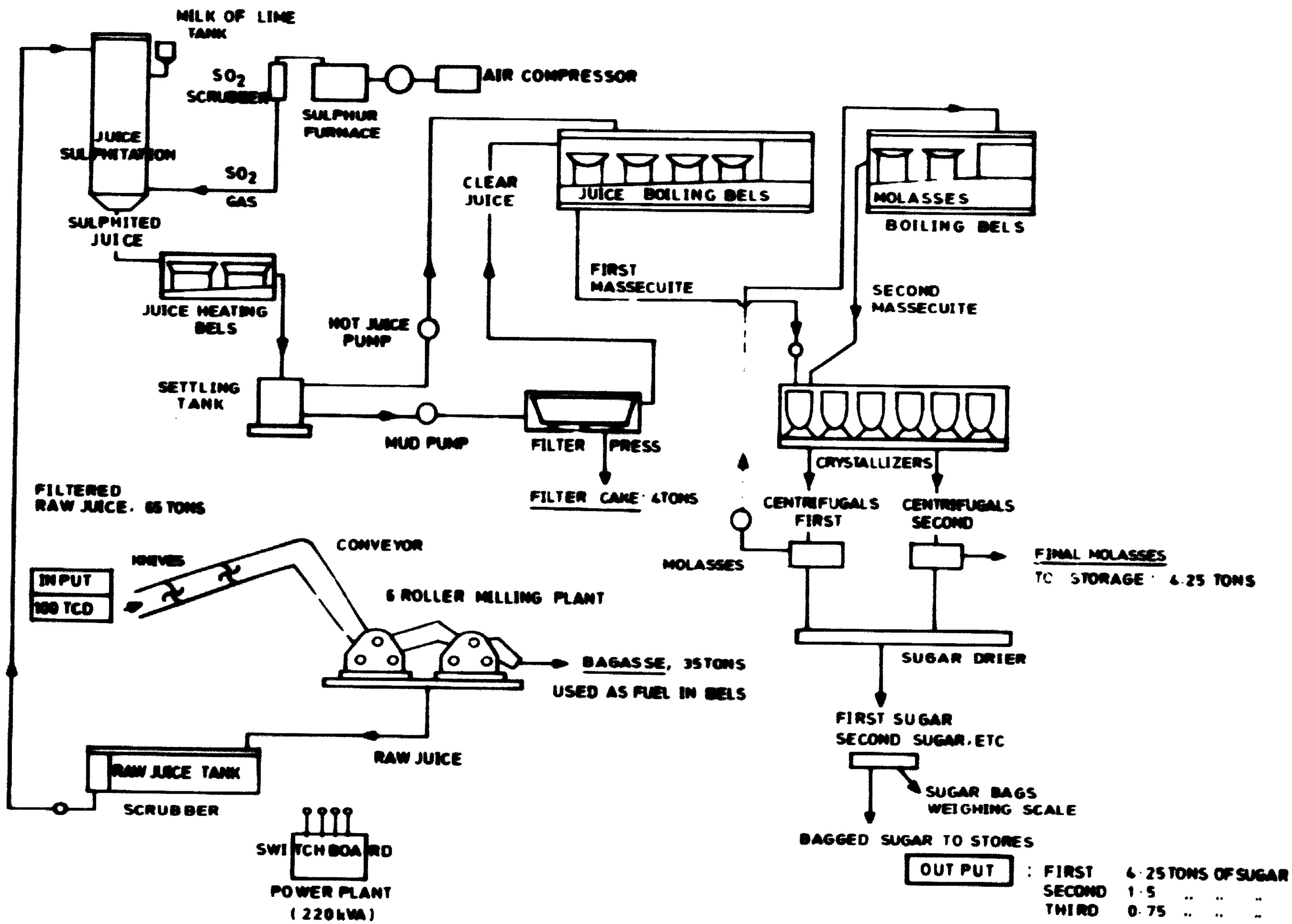
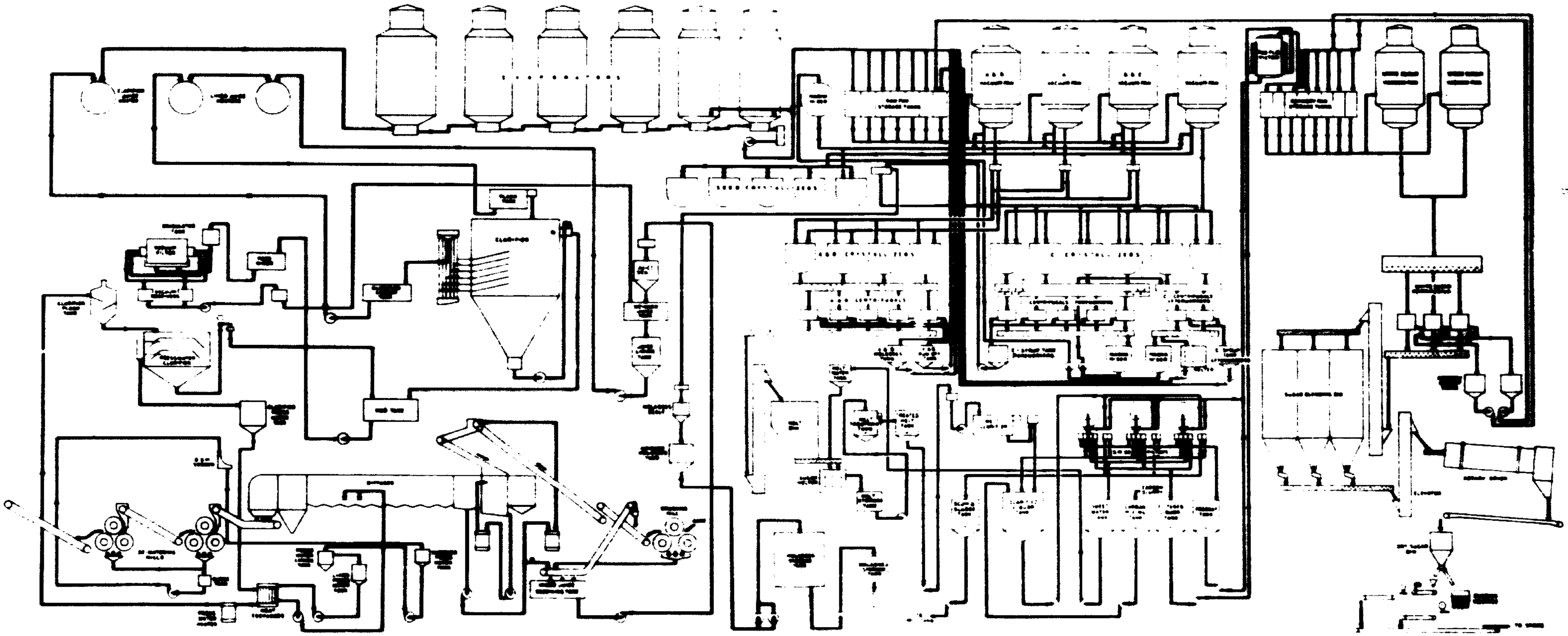


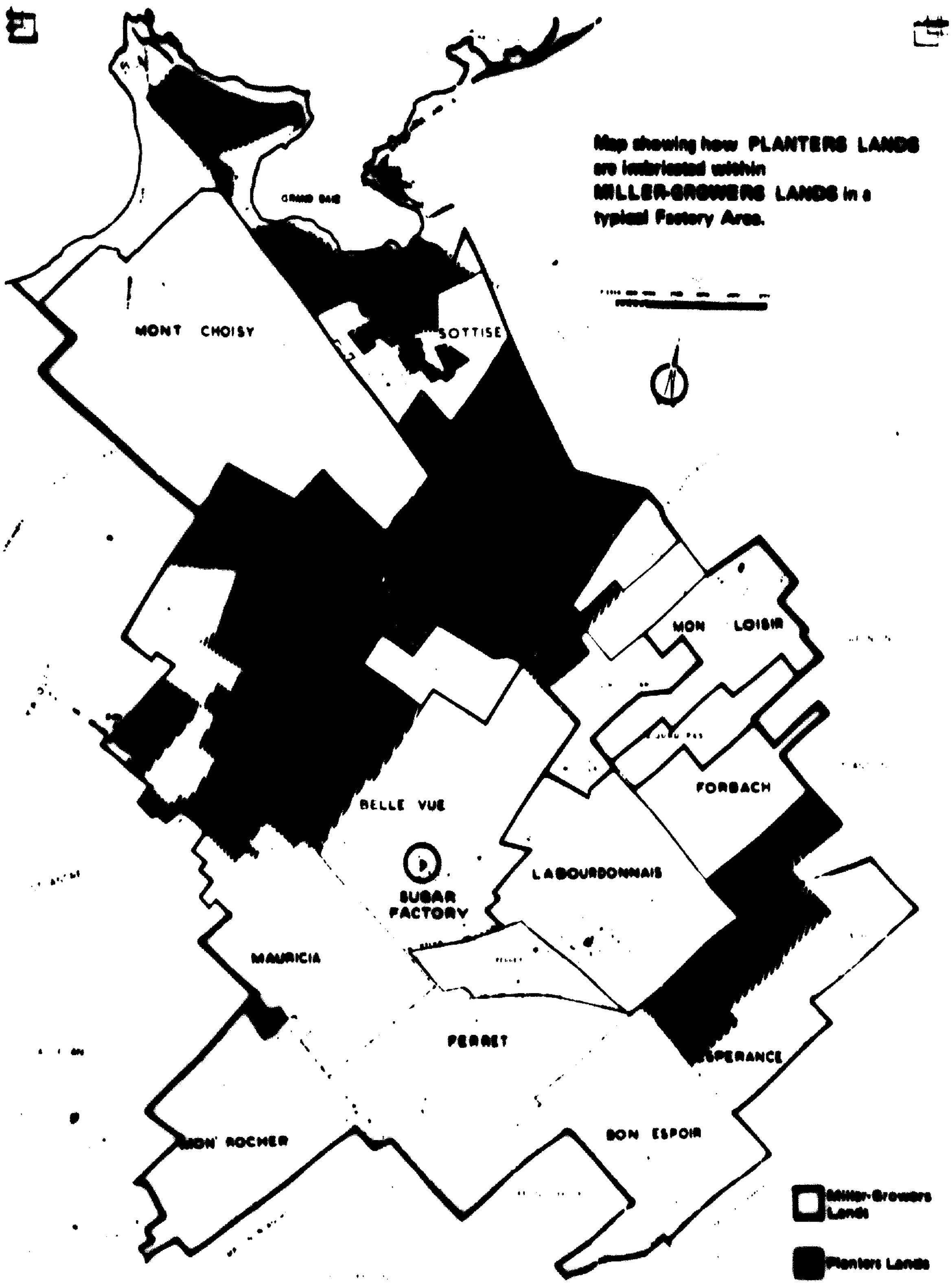
FIG. 6 **FLOW CHART FOR OPEN PAN SUGAR PLANT (100 TCD)**

LARGE SCALE VACUUM PAN SUGAR FACTORY



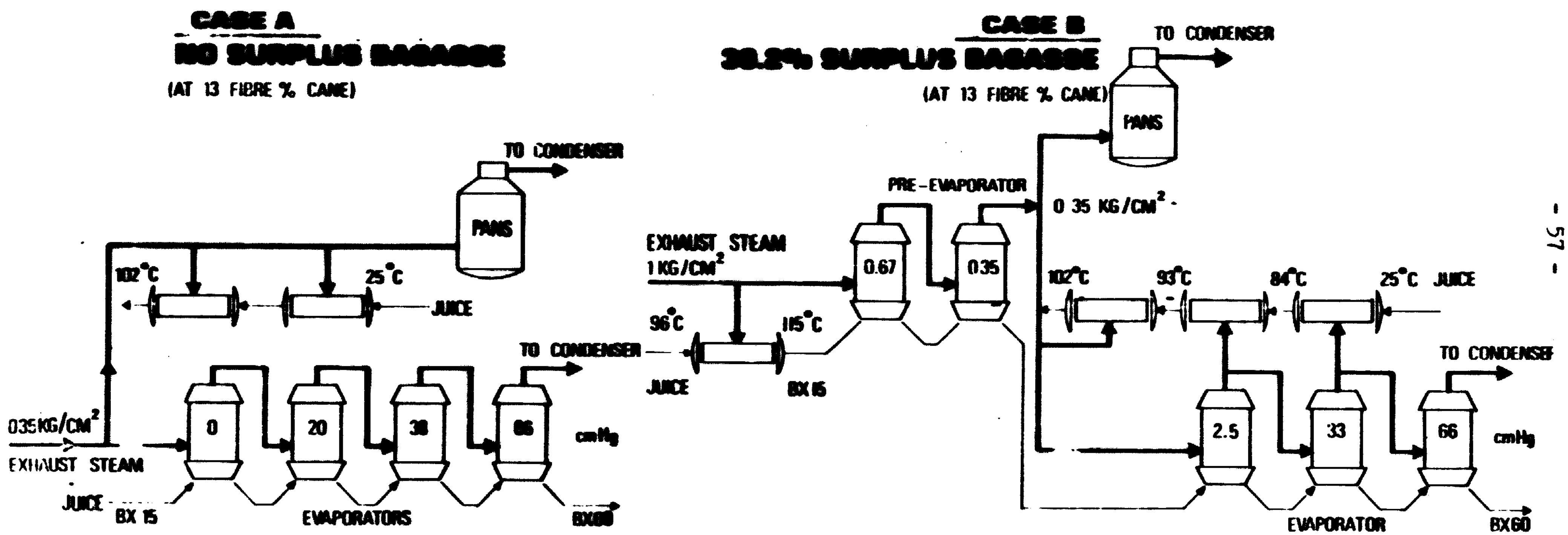
(Adapted from Mirrlees · Smith Ltd)

FIGURE 7


Map showing how PLANTERS LANDS are imbricated within MILLER-GROWERS LANDS in a typical Factory Area.
MONT CHOISY
SOTTISE
MON LOISIR
FORBACH
BELLE VUE
SUGAR FACTORY
LABOURDONNAIS
MAURICIA
FERRET
ESPERANCE
MON ROCHER
BON ESPOIR
Miller-Growers Lands
Planters Lands

FIGURE

RE—ARRANGEMENT OF BOILING HOUSE LEADS TO EXHAUST STEAM ECONOMY AND THUS TO SUBSTANTIAL FUEL SAVINGS



EXHAUST STEAM CONSUMPTION 52% CANE

EXHAUST STEAM CONSUMPTION 34% CANE

FIGURE 9

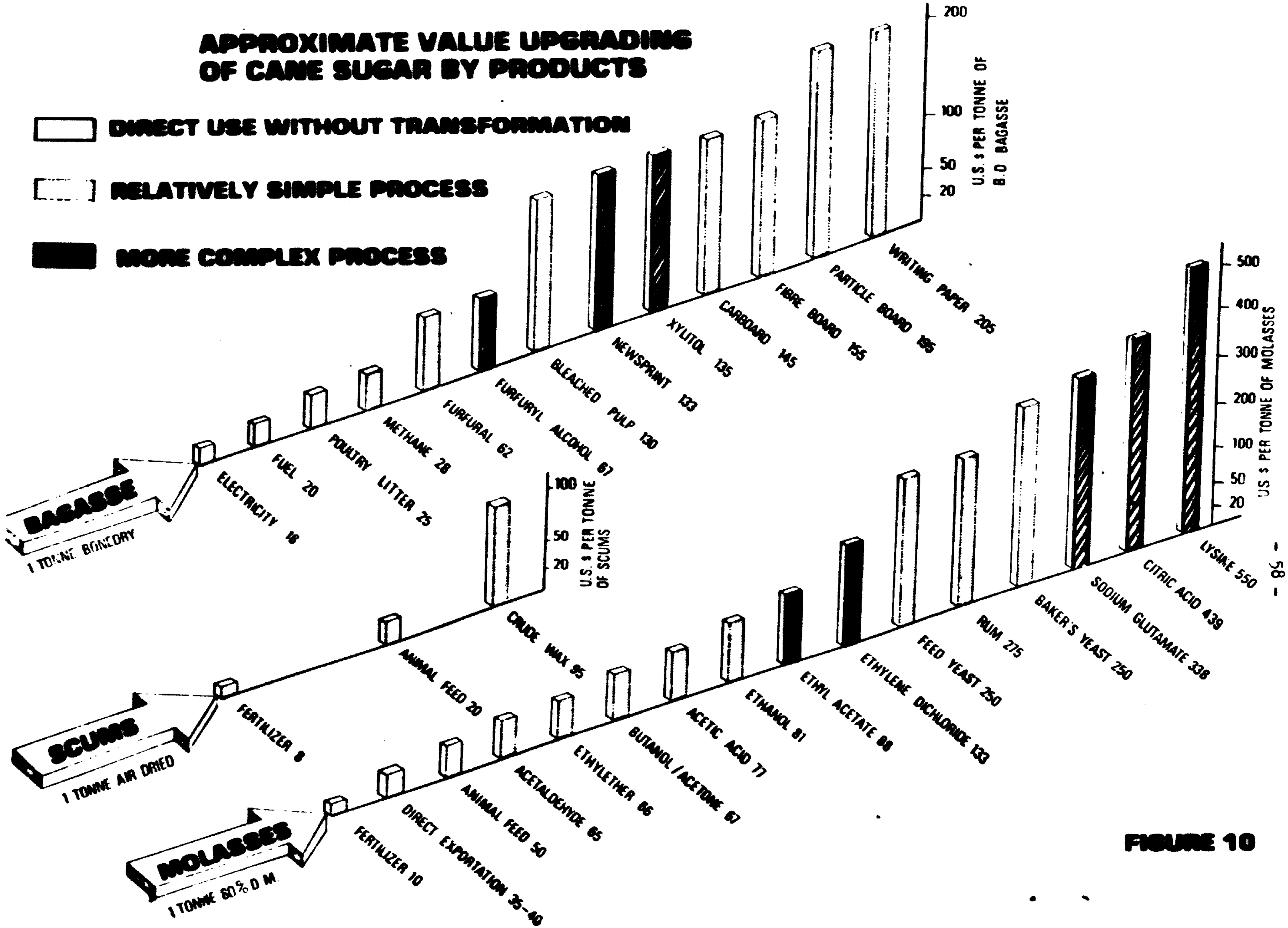

APPROXIMATE VALUE UPGRADING
OF CANE SUGAR BY PRODUCTS
DIRECT USE WITHOUT TRANSFORMATION
RELATIVELY SIMPLE PROCESS
MORE COMPLEX PROCESS
BAGASSE
1 TONNE BONEDRY
ELECTRICITY 18
FUEL 20
POULTRY LITTER 25
METHANE 28
FURFURAL 62
FURFURYL ALCOHOL 67
BLEACHED PULP 130
NEWSPRINT 133
XYLITOL 135
CARBOARD 145
FIBRE BOARD 155
PARTICLE BOARD 195
WRITING PAPER 205
U.S. $ PER TONNE OF B.D BAGASSE
200
100
50
20
SCUMS
1 TONNE AIR DRIED
FERTILIZER 8
ANIMAL FEED 20
CRUDE WAX 95
U.S. $ PER TONNE OF SCUMS
100
50
20
MOLASSES
1 TONNE 80% D M.
FERTILIZER 10
DIRECT EXPORTATION 35-40
ANIMAL FEED 50
ACETALDEHYDE 65
ETHYLETHER 66
BUTANOL / ACETONE 67
ACETIC ACID 77
ETHANOL 81
ETHYL ACETATE 88
ETHYLENE DICHLORIDE 133
FEED YEAST 250
RUM 275
BAKER'S YEAST 250
SODIUM GLUTAMATE 338
CITRIC ACID 439
LYSINE 550
US $ PER TONNE OF MOLASSES
500
400
300
200
100
50
20

FIGURE 10

EXAMPLE OF THOROUGH UTILIZATION OF CANE SUGAR BY PRODUCTS

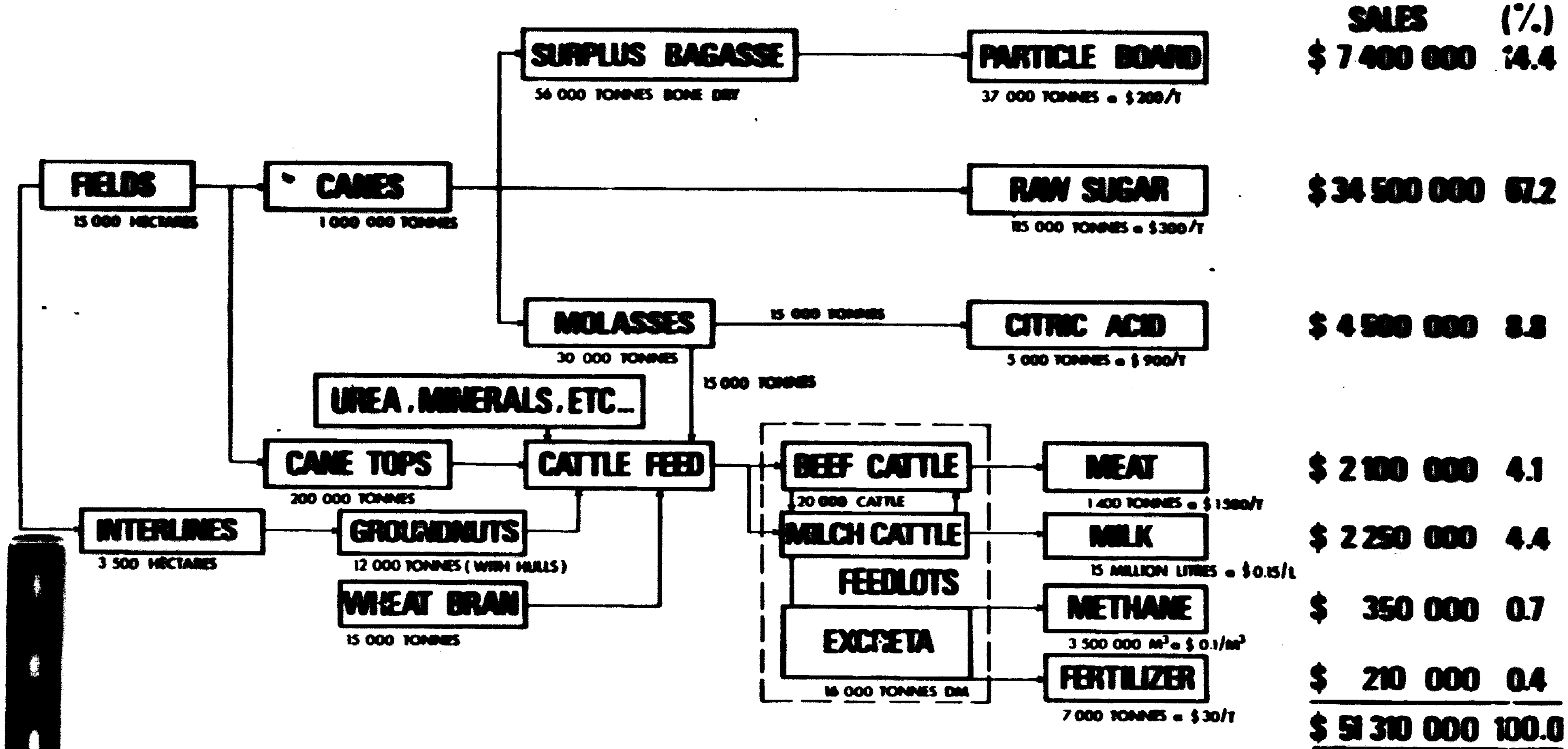


FIGURE 11

B-11

79.11.14