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ENVIRONMENTAL AND ECONOMIC IMPACT OF ALTERNATIVE AGRICULTURAL SUGAR TECHNOLOGIES 1/

by

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CONTENTS

ENVIRONMENTAL AND ECONOMIC IMPACT OF ALTERNATIVE AGRICULTURAL SUGAR TECHNOLOGIES

The purpose of this paper is to present some preliminary findings from a study of alternative agricultural technologies which could be used in a variety of African conditions to produce sugar cane. Production is taken as comprising a process which stretches from land preparation (ploughing, harrowing and furrowing) to the delivery of the cut cane to the cane table in the sugar factory. The study is part of a larger investigation into the environmental and economic impact of alternative sugar technologies, and the results will be integrated into those of the wider work. To some extent, however, the agricultural operations are self-contained. They certainly offer interesting opportunity for examining environmental and economic interactions, particularly perhaps with regard to choices among manual and mechanical methods of harvesting and transportation of the cane - the operations which are most considered in the present paper.

It is convenient, before further justifying the emphasis on harvesting and transportation, to set down - somewhat arbitrarily - the various stages of agricultural production schematically and in sequence. Thus:

STAGES IN THE PRODUCTION OF SUGAR CANE

PLANT CROP CULTIVATION

1. LAND PREPARATION
   - PLOUGHING
   - HARROWING
   - FURROWING
2. PLANTING
3. RIDGE FLATTENING
4. MOULDING
5. WEEDING

—FERTILIZER APPLICATION

RATOON CROP CULTIVATION

1A. TRASH RAKING

2A. CHISEL PLOUGHING

3A. RATOON RESHAPING

6/4A. HARVESTING OF CANE

7/5A. LOADING OF CANE

8/6A. TRANSPORTING OF CANE

The emphasis then is on three of eleven distinct (or at least distinguishable) operations.[1/] This is because - whether entirely manual or entirely mechanical regimes are being considered - these operations account for much of the total capital cost and provide much of the total employment associated with the agricultural operations as a whole. Moreover, there are reasons to believe that critical and far-reaching choice is, as a matter of fact, more likely to be made in the near future with respect to harvesting and transportation than it is in connection with pre-harvest

1/ In the final study all stages will be fully considered.

activities. In principle the latter could be undertaken manually, wholly mechanized or carried out manually at some stages and mechanically at others. In practice mixed regimes prevail in Africa and changes in these are likely to be gradual and limited in their overall impact in the foreseeable future. At present sugar cane is normally cut by hand and mechanically loaded and transported. There are now some pressures to replace manual with mechanical cutting - with implications for the environment, investment, profitability and employment.[2/] Consequently the remainder of the paper is largely concerned with manual and mechanical alternatives at the relevant stages. It is organized in three parts. The first comments briefly on scope and methodology; the second presents and discusses some economic results; and the third deals with the relationship between the alternative technologies and the environment.

2/ The underlying field work has established (a) that mechanical harvesting is under active consideration in one or two places; and (b) that the manufacturers of relevant equipment are actively seeking to extend their markets.

I. SCOPE AND METHODOLOGY

As can be seen from its title, this paper is concerned with both the environmental and economic implications of alternative sugar technologies. The definition and measurement of the pertinent effects are complex; and the design of readily applicable guidelines which would make it possible to weigh both environmental and economic considerations in the balance and arrive at a single, unambiguous decision indicator poses some near intractable problems.[3/]

It is, however, convenient to note that on one view the use of modern (or at least 'sophisticated') technology is inimical to the environment: it depletes non-renewable resources at unacceptably rapid rates, causes physical pollution, is personally and culturally disruptive and gives rise to an economic and social dualism in developing countries which is grossly inequitable and hence unstable. There is, of course, a contrary view in which many non- (indeed anti-) Marxists would join with Marx in seeing industrial technology as a means of rescuing people from "the idiocy of rural life". Nevertheless it is useful to begin with the presumption that modern technology is, on balance, not environmentally beneficial since this can greatly simplify the making of environmental *and* economic judgement. Thus, if modern technology shows up badly on economic comparisons with

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3/ For a fuller discussion of these matters see James Pickett, "Measuring the Environmental and Economic Impact of Alternative Technologies".

alternatives, then there is nothing more to be said - environmentally or economically. If it shows up well, then, of course, many questions remain open. Unless, however, an integrated approach to economic and environmental assessment is possible, or unless there are strong reasons for reversing the order of consideration, there is nothing to lose and possibly something to gain from taking the economic first. At all events, that is done here.

The economic comparison made is that between manual cane cutting and mechanical loading and transportation on the one hand and fully mechanized operations on the other. The comparison covers six agricultural regimes and is made for two levels of wages - broadly those prevailing in East and West Africa respectively in 1976/1977. The agricultural regimes are as follows:

I: Plantation, irrigated, long-season (216 days)[a/]

II: Plantation, rainfed, long-season

IIA: Outgrowers, rainfed, long-season

III: Plantation, irrigated, short-season (120 days)[a/]

IV: Plantation, rainfed, short-season

IVA: Outgrowers, rainfed, short-season

a/ Allows for 20 per cent down-time in the factory, so that 'theoretical' season lengths are 150 and 270 days for short and long respectively.

Profitability, investment and employment provide the main focus for the comparisons and the costs underlying them are calculated at 'market' prices. Only one level of scale is considered - that which requires a daily delivery of cane of 4,800 tonnes.

Investment is the discounted value of all capital equipment that would be required - over a project period of 25 years - for each of the combinations of agricultural regime and technology covered by the study. It thus represents a measure of the investible funds which would be needed to start the feasible 'projects' considered. Employment covers all grades of labour up to and including foremen, and is characterized simply as 'skilled' and 'unskilled'. Ideally, profit should be measured by present value, the calculation of which would require an estimate of the whole-stalk price of cane and - to be fully rigorous - even more detailed cost estimates than those embodied in this paper.[4/] Further estimation and more detail will be included in the final study. In the meantime, profitability is judged by annual costs - comprising labour costs, the operating costs of equipment, depreciation and an allowance of 10 per cent return on capital.

4/ Fuller details of cost structures and underlying assumptions are given in Annex 1.

II. THE ECONOMIC COMPARISONS

Some economic characteristics of alternative technologies for harvesting, loading and transporting sugar cane under different agricultural regimes and at 'low' and 'high' wage rates are described and quantified in Table 1. The most striking feature of the data is the basic uniformity they display across agricultural regimes and economic characteristics. Thus, the required capital investment is always greater when mechanical rather than manual harvesting is employed; manual harvesting invariably uses more unskilled and less skilled labour than does the mechanical alternative; and the wholly mechanical is invariably more costly (hence presumably less profitable) than the combination of manual cutting with mechanical loading and transporting.

As hinted earlier, on one view there is nothing more to be said. The introduction at this time of mechanical harvesting in African conditions would put additional demands on investible funds and skilled labour (widely believed to be relatively scarce factors), provide less employment for the unskilled (who are available in relative abundance) and would apparently make less commercial profit than traditional cane cutting methods. If the environmental consequences of mechanical were in addition less desirable than manual harvesting, then the case against its introduction would seem to be very strong indeed.

TABLE 1 Some Economic Characteristics of Alternative Technologies for Harvesting Loading and Transporting Cane under different Agricultural Regimes and at 'Low' and 'High' Wage Rates

Economic Characteristics	Agricultural and Technological Regime											
	I		II		IIA		III		IV		IVA	
	A	B	A	B	A	B	A	B	A	B	A	B
Capital Investment (US $ million)	5.9	8.7	6.0	12.1	10.5	26.1	5.6	14.2	6.5	28.1	11.2	67.3
Employment (number)												
unskilled	1,364	178	1,681	275	2,670	444	2,396	299	2,996	516	5,160	1,070
skilled	178	198	212	280	591	652	166	266	204	456	554	1,340
Annual Operating Costs (US $ million)												
'low' wage	3.2	3.7	3.8	5.3	5.2	9.8	2.5	4.0	3.1	7.4	4.6	16.8
'high' wage	4.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Legend: Roman numerals represent agricultural regimes as above.

A = Manual cutting/mechanical loading and transportation.

B = Wholly mechanical technology.

TABLE 2 Some Economic Characteristics of Alternative Technologies for Harvesting Loading and Transporting Cane under different Agricultural Regimes and at 'Low' and 'High' Wage Rates

Economic Characteristics expressed in per cent: A_I = 100			Agricultural and Technological Regime									
			II		IIA		III		IV		IVA	
	A	B	A	B	A	B	A	B	A	B	A	B
Capital Investment	100	148	100	202	100	248	100	254	100	432	100	600
Employment												
unskilled	100	13	100	16	100	17	100	12	100	17	100	21
skilled	100	111	100	132	100	110	100	160	100	223	100	242
Annual Operating Costs												
'low' wage	100	116	100	139	100	188	100	160	100	239	100	365
'high' wage	100	105	100	127	100	166	100	129	100	191	100	283

Legend: Roman numerals represent agricultural regimes as above.

A = Manual cutting/mechanical loading and transportation

B = Wholly mechanical technology.

The earlier discussion notwithstanding, it is important to pay some specific attention to the environmental aspects of the alternative technologies. Before doing so, however, it is worth examining the data of Table 1 more closely and thereafter considering whether - even in the light of the evidence of the table - there is anything to be said in favour of mechanical harvesting. To facilitate closer examination of the results of Table 1, the data have been re-worked and presented as percentages in Table 2. The relevant percentages may be examined to throw light on the question of whether the mechanical harvesting comes sufficiently close at any point to being as profitable as manual cutting to warrant serious consideration. Related to this they may be used to illuminate differences in relative profitability across agricultural regimes.

"Sufficiently close" is a term which cannot be given precise interpretation. Here it is enough to ask how often the costs of the wholly mechanical option are within 10 per cent of the manual alternative. The answer is in only one - the plantation, irrigated, long-season regime at the 'high' wage rate - of the twelve comparisons made in the table. In this one instance, the costs of the two alternatives are within 5 per cent of each other. To choose the mechanical option would be to increase investment costs by 48 per cent and lower unskilled employment by more than 80 per cent. This single case apart, the mechanical technology is significantly more expensive than manual cane cutting in all situations - being from 16 to 265 per cent more costly. Not surprisingly the mechanical option fares less well in short- than in long-season operations, and less well when cane is supplied by outgrowers than when it is grown in plantations.[5/]

It should be noted that - again not surprisingly - the increase in investment costs associated with a preference for mechanical harvesting is lower in the case discussed above than in any other situation covered by Tables 1 and 2. Indeed, the relevant rise in capital costs otherwise ranges from 102 to 500 per cent; and in virtually all cases the fall in unskilled employment is at least 80 per cent.

The comparisons made thus far are distinctly unfavourable to mechanical harvesting. It is consequently appropriate to ask whether - managerial convenience and blind faith in modern technology apart - there are any economic reasons which would justify its adoption in Africa. Stretching a point, there might be two. In some circumstances and in some locations labour - even in conditions of general surplus - may not be available at the times and to the extent required. Consequently, the choice of mechanical harvesting might be justified as an act of economic realism. In the light of all that has been said, however, this excuse would have to be very well documented indeed before it would be acceptable.

5/ It is worth remarking that outgrower costs are greater than plantation costs for manual cutting also, although the relative difference is obviously less than that associated with mechanical harvesting.

As has been seen, the demands of mechanical harvesting on skilled labour are relatively greater than those of manual cutting - although the absolute numbers are not enormous in either case. Thus the claim could be made that mechanical harvesting - directly and indirectly - would contribute more to skill formation than the alternative. True as this might be, however, the cost in other directions would seem on present evidence to be excessive.

III. ENVIRONMENTAL CONSIDERATIONS

Environmental considerations are frequently classified into physical, social and economic. Like all such classifications, this one is to be justified more by analytical convenience than by correspondingly clear-cut distinctions in reality. It is nevertheless useful and it is proposed to consider the relationship between the alternative technologies and the economic, social and physical environment in turn.

In African countries the dominant feature of the economic environment is that of widespread poverty and a concomitant lowness in levels of living. Given this, environmental improvement should take the form of increasing access for more and more people to more and more productive employment (and hence income); and, related to this, of generating and prudently re-investing the largest possible surplus. In this regard, consideration has already been given to the economic environment above and the evidence of Table 1 seems clearly to be in favour of manual cane-cutting.

The question of the social environment is less easily disposed of in a satisfactory way and such short compass. This is because the links between social factors and economic growth and development are more complex than those between technology and growth, and because in the present context there might be more social implication in a comparison between outgrower and plantation agriculture than in that between alternative technologies. Social attitudes shape and are in turn shaped by developmental goals and aspirations. This obvious fact, to be turned to operational advantage, suggests a need to define goals and take stock of aspirations. Ideally such definition and stock-taking should be specific to particular societies. Such specificity would require a series of major studies, in the absence of which recourse has to be had to such general suggestion as that made by Gunnar Myrdal that development is a process of moving entire social systems upwards.[6/] For present purposes, this general definition can be connoted to include increases in income, numeracy, literacy, health and health provision, skills and social cohesion. This list is simultaneously incomplete, overlapping and perhaps rather a lot to put on the shoulders, as it were, of a single industry study. It does, nevertheless, provide a basis for consideration - albeit somewhat disjointed - of the relationship between agricultural sugar technology and the social environment.

In this regard, the first thing to be said is that unless the economically attractive technology can be shown to have strongly undesirable social effects it must be presumed to be socially beneficial - if only because the greater the economic surplus, the greater in principle the scope for social betterment. Put thus, the important question becomes: is manual cane-cutting socially desirable? In an ideal society probably it is not since it comes too close to being brute labour to be an acceptable human activity in the modern world.

6/ In, for example, his *Asian Drama*, The Allen Lane Press, 1972.

The question can, however, only properly be answered relative to present circumstances. In many countries these make manual cane-cutting more acceptable, particularly when the wage rate is significantly higher than in subsistence agriculture. As compared to mechanical harvesting, manual operations probably contribute less to numeracy, literacy and skill formation. They contribute more, however, to employment (and increased incomes for more people) and thus to the prospect perhaps of greater skill formation in the future. Moreover, the fact that manual operations spread opportunities more widely probably contributes to social cohesion, so that on a crude calculus, the manual operations can be judged to be socially preferable to the alternative.

With regard to the physical environment, the main considerations are more readily identifiable - but not necessarily more readily judged - that those which bear on the social environment. Here attention is focused on two main elements: cane-burning and the impact of mechanical harvesting on the soil and vice versa.

Where sugar cane is grown in blocks of adequate size with sufficient clear width around to act as a fire break, it is usual to burn the cane the day before it is due to be harvested. In manual cane-cutting productivity is at least doubled by burning off the dead leaves or trash. Moreover, pre-harvest burning improves the working conditions of the cutters. Thus in many countries the cool, moist micro-climate within a cane crop is an ideal habitat for snakes; and cane leaves are very sharp-edged and hence easily cut into the skin. Mechanical harvesting tends also to be geared towards burnt cane but several types of machine can cut green cane, so that if cane-burning were a serious environmental problem this factor could favour the mechanical operation.

The overall effects of cane-burning are, however, difficult to judge, there are both detrimental and beneficial effects. The former include the neglect - at least at larger scales of operation and for economic reasons - of cane tops, which have traditionally been an important source of animal feedstuffs; and the end of the practice of leaving the cane trash scattered (or windrowed) to act as a surface mulch. In certain soils and climatic conditions this mulch can protect the soil from the effects of torrential rain; conserve moisture; suppress weeds; and have a slight fertilizing effect. The major disadvantage of surface litter is that it can carry pests and disease to the following crop. Moreover, without windrowing - i.e. without additional cost - the litter would inhibit ratooning the same way as it suppresses weed growth. Given the difficulty of striking a balance between adverse and desirable side effects of cane-burning in relation to the soil and its cultivation, it is worth noting that the adverse effects can - without environmental damage - be overcome, for example, by the judicious application of fertilizer, deep ploughing and scientific weed control. Such measures would vary with agricultural regime, but not with harvesting technology.

A more obvious environmental effect of cane-burning is air pollution. In most developing countries this question has probably not been examined very closely. (Sugar cane tends to be grown in predominantly rural areas while the tendency in environmental lobbying is to start on the cities and rivers.) Work has, however, been done on it in North America and Australia. In Florida one study has shown that air quality does not change significantly between the harvest and non-harvest seasons although in certain local situations nuisance levels of particulate matter may be reached[7/] although in some parts of the world cane-burning is regulated.

The major physical environmental impact of the introduction of mechanical harvesting would be on the soil, which in turn can significantly influence the efficiency of such harvesting. Thus in Australia in recent years mechanical harvesting has been generally productive. In unusually wet weather conditions (such as those of 1975), however, it is impossible to harvest the full cane crop because the soil becomes saturated and hence extremely muddy. It is interesting to note that before the industry became completely dependent on mechanization cane-cutters would have been available in such an emergency to supplement the mechanical harvesters.

7/ E.R. Hendrickson, *Status of Air Quality in the Sugar Cane Area of Florida*, presented at the Annual Meeting of the American Society of Sugar Cane Technologists, Palm Beach, Florida, October 1970.

As it was (and is) in these conditions the mechanical harvester travels along the furrow bottom while cutting the cane stalks at or just below ground level with greater difficulty than usual; while the effect on the soil is compaction, surface capping and general loss of structure in the top soil. The effects of this will be evident in the poor ratoon crop to follow. These adverse conditions would be especially marked in tropical black clay soils (*vertisols*) which become very plastic ans sticky after rain. The red soils (*oxisols*) on the other hand have a structure which is much more suited to mechanical operations, being well drained with a strong granular structure. This soil type is of very low inherent fertility however and so requires more additional inputs. The black soils are of much higher fertility but are very difficult to work either by traditional or modern methods.

The use of mechanization in a fully irrigated regime would not,under normal circumstances,be faced with these problems, since the normal practice is to stop giving water for 1½-2 times the irrigation interval before harvest. This gives the soil time to dry out before machines are put on the land.

The impact of agricultural mechanization is dependent not only on the local physical conditions of soil and terrain, but also on the prevailing climatic conditions and the need to carry out certain operations within a given period of time. To achieve the necessary economic goals with the minimum amount of environmentaldamage, the skill of the agricultural staff and extension service in basic principles and local knowledge, and the availability of equipment, in the case of mechanized operations, to make the fullest use of suitable working conditions would be of vital importance. From what has earlier been said of the shortage of skills and from the other advantages of manual cutting, this specification can in present African circumstances be seen as further argument in favour of that technology.

ANNEX I

The main concern of this paper has been to compare and contrast two alternative methods of cane harvesting and transport and as such the cost data used in the calculations have focused on those elements which are substantially different between the technologies. In other words the unit cost figures in Table 1 do not include a number of items which do not vary.

For example, the manual and mechanical harvesting technologies are compared for each climatic/organizational regime assuming the same yields, and hence areas in each situation. Consequently inputs such as fertilizer, which would have a cost per hectare can be taken as constant. The question of varying fertilizer application may arise if it were considered preferable to mechanically cut green cane as opposed to manually cutting burnt cane.

An item which has been excluded is the cost of disinfectant for cane knives. This is obviously only required in the manual operation but there are two possible means of use with considerable difference in cost. The disinfectant can be carried to the cutters for frequent dipping of the knives or the knives may be dipped only once per day. Before including the cost of the material it is hoped to be able to assess the relative efficiency of each method in the control of disease.

In order to show the build up of the agricultural model details of assumptions and calculations are presented for Regime I, the irrigated, plantation supplying 4800 tcd for 216 days.

Cane Cycle - plant crop (20m)
4 ratoons (16, 16, 15, 15 m)
land preparation (2m)

Land Use Efficiency - 97.6 per cent

Cane yield - 10t/ha/m

Plantation area - 8,852 ha plus 53 ha for seedcane, increased by 50 per cent for non-cane land = 13,358 ha.

Annual Rotation Area - 1265 ha

Average trip length - 8.8 km

Manual cane-cutting, mechanical loading and transport

Burnt cane @ 5t/man day = 960 men with 1 headman per 40 cutters.

Loading by grab loader @ 810 tc/24 hrs = 6 (+ 2 spare); each working alongside 2 crawlers for infield haulage. 10 labourers per grab loader for picking up dropped cane. Irrigation ditches closed by one crawler and 5 labourers at each of two harvesting sites per day.

Cane transport is by 75hp wheeled tractor pulling 4 x 4.5t trailers, each doing 13 trips per day.

21 tractors + 4 spare required, each with 3 sets of 4 trailers (300).

Machinery requirements		Running Costs/Hr
Wheeled tractors	32	$5
Crawlers	19	$7.3
Grab loaders	8	$12.4
Light units	5	$ 4.0
Cane trailers	300	$ 0.5
Other trailers	6	$ 0.5
Tanks	6	-
Knives	1600	-

Total cost $2.11 m

Running costs $1.88 m p.a. at low wage rates
$2.16 m p.a. at high wage rates

Labour requirements	Permanent	Temporary
Foremen	8	
Field Assistants	16	
Headmen	16	26
Clerks	2	8
Operators		74
Drivers		104
General labour		370
Cane cutters		960

Total cost at low wage rates $0.48 m
at high wage rates $0.97 m

Unit Costs =			
	Running costs	$1.88m	(2.16)
	Depreciation	$0.65m	(0.65)
	Labour	$0.48m	(0.97)
	10% return	$0.21m	(0.21)
		$3.23m	3.99m

Mechanical harvesting, loading and transport

Burnt cane is topped, cut and chopped by a mechanical harvester, working at a rate of 1050 tc/24hrs = 5 harvesters + 1 spare. Working alongside are 2 self-propelled (crawler) trailers which carry 8t each.

Chopped cane is tipped into sets of 4 x 4t trailers pulled by 75hp wheeled tractors, each doing 10 trips a day.

30 tractors + 6 spare required each with 2 sets of 4 trailers (288)

Machinery requirements		Running costs/hr
Wheeled tractors	42	$ 5.0
Crawlers	3	$ 7.3
Cane Harvesters	6	$15.0
Infield transporters	12	$10.0
Light units	5	$ 4.0
Cane trailers	288	$ 0.5
Other trailers	1	$ 0.5
Tanks	1	-

Total cost	$3.21m
Running costs	$2.19m p.a. at low wage rates
	$2.52m p.a. at high wage rates

Labour Requirements	Permanent	Temporary
Foremen	8	
Field Assistants	16	
Headmen	8	2
Clerks	2	8
Operators		62
Drivers		136
General labour		168

Total cost at low wage rates $0.16m

at high wage rates $0.31m

Unit costs =			
	Running Costs	$2.19m	(2.52)
	Depreciation	$1.05m	(1.05)
	Labour	$0.16m	(0.31)
	10% return	$0.32m	(0.32)
		3.72m	4.20m

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