The Effect of Rubber Price and Yield per Acre on Estate Production Costs

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The relation between estate production costs per pound (expressed as revenue costs and total f.o.b. costs) and the yield per acre per annum is derived from a sample of companies. The influence of falling rubber price on this relation is examined. Estimates are made of the proportions of Malayan estate acreage and production which are liable to operate unprofitably at times of low price unless improvements in productivity are made. The constituent items in the total f.o.b. costs of production are discussed.

DATA

Production cost information is not readily available for all Malayan estates. The present study is mainly based on 115 companies during the year 1961.

The data for 1961 have been supplemented by results for the third quarter of 1960 and the first quarter of 1962 to enable the recent effects of marked price change to be studied.

DEFINITION OF PRODUCTION COSTS

Two main types of cost per pound are discussed:

(a) *Revenue cost per pound.* This corresponds approximately to an estate's direct operating costs and includes:

(i) Upkeep of mature areas (including manuring, weeding, control of pests and diseases, maintenance of drains, roads, and bridges).
(ii) Tapping and collection (including transport of latex to factory, transport of tappers, yield stimulation, tools).
(iii) Manufacture (including factory labour, power, repairs).
(iv) General charges (e.g. estate supervision, housing and other indirect labour costs, medical services).
(v) Packing and despatch (to a Malayan port or Singapore).

(b) *Total f.o.b. cost per pound.* This is revenue cost plus the following:

(i) Export duty and cesses.
(ii) Depreciation of buildings, machinery, and transport, and depreciation of trees.
(iii) Company administration and selling charges.

The total f.o.b. cost represents all costs up to the Malayan port. Landed cost, say in London, would require additional ocean freight, insurance, and landing charges amounting to about 6 cts per lb. Revenue cost is regarded as containing little or no direct costs arising from replanting and maintenance of immature areas (although the general charges item seems likely to bear some burden). Provision for replanting and upkeep during immaturity is embodied in the depreciation cost. Accounting procedures vary with companies, but the above definitions of revenue costs and total f.o.b. costs are believed to be generally applicable to the company figures analysed.

RELATION BETWEEN TOTAL F.O.B. COST PER LB AND YIELD PER ACRE PER ANNUM

The relation between the total f.o.b. cost per lb, (y), and the yield per acre per annum, (x), is shown graphically in *Figure 1* for the year 1961, and also for the two quarterly periods. Each point on the graphs corresponds to the mean of a cost group and represents a number of companies. Linear regressions have been fitted by weighting according to the number of companies. Weighting according to production gives similar equations. There is some indication of curvature in the graph for the 1st quarter of 1962, and in fact there are *a priori* grounds to expect a non-linear relation between certain components of the total f.o.b. cost per lb (e.g. tapping cost) and yield per acre. However, the empirical evidence of curvature is contributed by relatively few companies, and in view of

the wide variation of individual companies about the regressions, a simple linear approximation has been adopted.

The slopes of the three lines are not grossly different; hence a pooled slope has been determined and the regression equations recalculated. These parallel regressions are shown in *Figure 2* and the information summarised in *Table 1*.

Yields range from about 500 to 1100 lb per acre. The slope of the regression lines demonstrates that within this range there is an average fall of about 5 cts per lb in total f.o.b. costs with each 100 lb increase in yield per acre per annum. The displacement of the lines is a measure of the price influence.

RELATION BETWEEN REVENUE COST PER LB AND YIELD PER ACRE PER ANNUM

The corresponding relationships for revenue cost per lb and yield per acre are obtained from the f.o.b. equations of *Table 1* by deducting the cost items listed above under 'Total f.o.b. cost per pound.' Details are given in *Table 2*.

Export duty and cesses vary with the price. Details of the export duty and cesses are given in *Figure 3*. Replanting cess is excluded from the total export duty and cesses because it is eventually refunded. Administration and selling charges average about 3 cts per lb and are regarded as constant. The total f.o.b. costs per lb contain an arbitrary depreciation cost which is based on a fixed depreciation value per acre for all companies. Consequently the depreciation cost per lb decreases with increasing yield per acre. For yields per acre per annum (x) in the range 500 to 1100 lb, the depreciation cost per lb adopted is closely approximated by:

$$\text{depreciation cost per lb, } d = 18.2 - 0.0112x \text{ cts}$$

For example at 500 lb per acre, depreciation is charged at 12.6 cts per lb, whereas

TABLE 1. RELATION BETWEEN TOTAL F.O.B. COST PER LB (y) AND YIELD PER ACRE PER ANNUM (x)

Period	Mean price RSS 1 Singapore (cts/lb)	No. of companies	Mean f.o.b. cost (cts/lb)	Mean yield per acre per year (lb)	Regression of y on x
3rd quarter 1960	103.5	120	71.8	802.7	$y=115.46-0.0544x$
Year 1961	83.5	115	63.7	802.1	$y=107.39-0.0544x$
1st quarter 1962	80.8	102	63.1	797.7	$y=106.49-0.0544x$

TABLE 2. RELATION BETWEEN REVENUE COST PER LB (y') AND YIELD PER ACRE PER ANNUM (x)

Period	Mean price RSS 1 Singapore (cts/lb)	Export duty and cesses (cts/lb)	Admin. and selling (cts/lb)	Depreciation (cts/lb)	Regression of y' on x
3rd quarter 1960	103.5	14.42	3.00	18.2 – 0.0112x	$y'=79.84-0.0432x$
Year 1961	83.5	8.40	3.00	18.2 – 0.0112x	$y'=77.79-0.0432x$
1st quarter 1962	80.8	7.32	3.00	18.2 – 0.0112x	$y'=77.97-0.0432x$

at 1100 lb per acre it is only 5.9 cts per lb. Further notes on this depreciation charge are given in *Appendix A*.

The three revenue cost regression equations derived in *Table 2* are also parallel, (with a slightly smaller slope than the three regression lines for total f.o.b. cost). The displacement of the revenue cost equation at a price of 103.5 cents per lb from the other two equations can be largely attributed to the influence of price on tapping and upkeep costs. There is a small contradiction between equations at 83.5 and 80.8 cents but this may be due to the fact that the sample companies are not identical in both periods.

The next step is to examine the extension of these revenue cost equations to other price conditions.

INFLUENCE OF PRICE ON REVENUE COST PER LB

Tappers on estates which accept the M.P. I.E.A. wage agreement receive a guaranteed daily wage dependent on the prevailing rubber price, and a bonus for poundage which depends on the yield potential of the trees but is independent of price. Other field workers on such estates receive a guaranteed daily wage depending on rubber price and the sex of the worker. The relations between the guaranteed wages of tappers and field workers and the price of RSS 1 are shown in *Figure 4*. For an average estate it is estimated that a fall in price of 10 cts per lb reduces a tapper's wage by 15 to 20 cts per day and reduces revenue cost by 0.8 to 1.1 cts per lb. The effect of a fall in price is greatest when the price level is low. This average reduction is confirmed by the revenue cost equations in *Table 2*. The fall in price from the 3rd quarter 1960 to 1961 averaged 20 cents per lb, and the corresponding revenue cost equations are displaced 2 cents. A more detailed example is given in *Appendix B*.

It could be argued that the reduction in tapping costs per lb with falling price would be more pronounced on low-yielding estates. This refinement is ignored in the present analysis because the overall effect of price on revenue cost is not very large and the observed relations between total f.o.b. costs and yields for different prices are reasonably parallel.

Other items of revenue cost per lb (e.g. manufacture, packing, general charges) are not automatically affected by price change, although during prolonged periods of low prices extra economies would obviously be considered.

EXTENSION OF THE REVENUE COST EQUATIONS FOR A WIDE RANGE OF RSS 1 PRICES

Interpolating in *Table 2*, it is estimated that the equation relating revenue cost per lb and yield per acre per annum at an RSS 1 price of 85 cts per lb is:

TABLE 3. EQUATIONS RELATING REVENUE COST PER LB (y′) AND YIELD PER ACRE PER ANNUM (x) AT DIFFERENT PRICES OF RSS 1

Price zone (cts/lb)	Mid-value (cts/lb)	Relative change in guaranteed daily wage (cts/day)	Change in revenue cost (cts/lb)	Regression equations
50—60	55	−55	−2.9	$y' = 75.25 - 0.0432x$
60—70	65	−35	−1.9	$y' = 76.25 - 0.0432x$
70—80	75	−15	−0.8	$y' = 77.35 - 0.0432x$
80—90	85	0	0	$y' = 78.15 - 0.0432x$
90—100	95	+15	+0.8	$y' = 78.95 - 0.0432x$
100—110	105	+30	+1.6	$y' = 79.75 - 0.0432x$

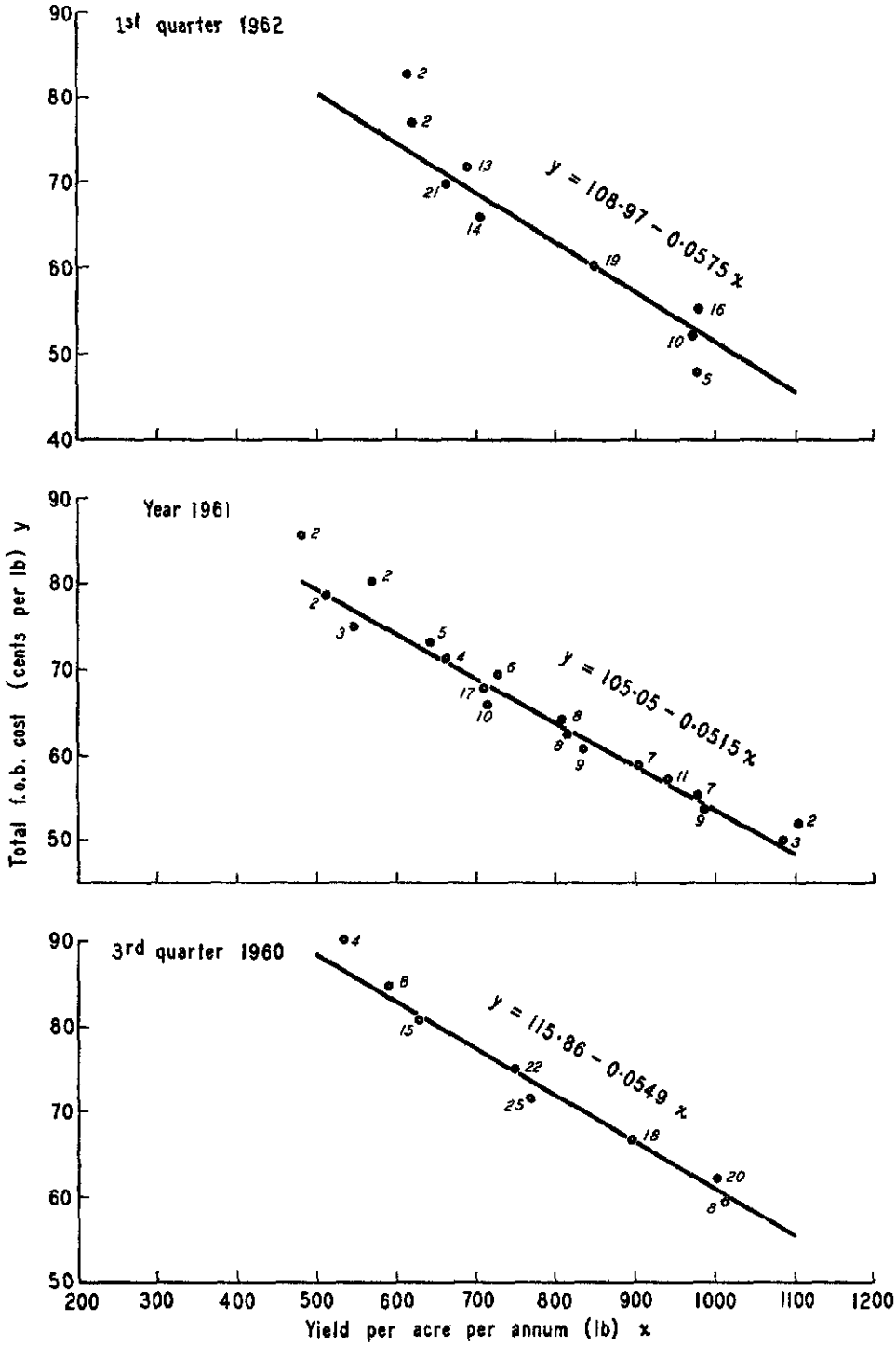

Figure 1. Relation between total f.o.b. costs (cents per lb) and yield per acre per annum (lb).
Note: The number of companies contributing to each point on the graph is indicated, e.g. 2 denotes the mean of two companies.

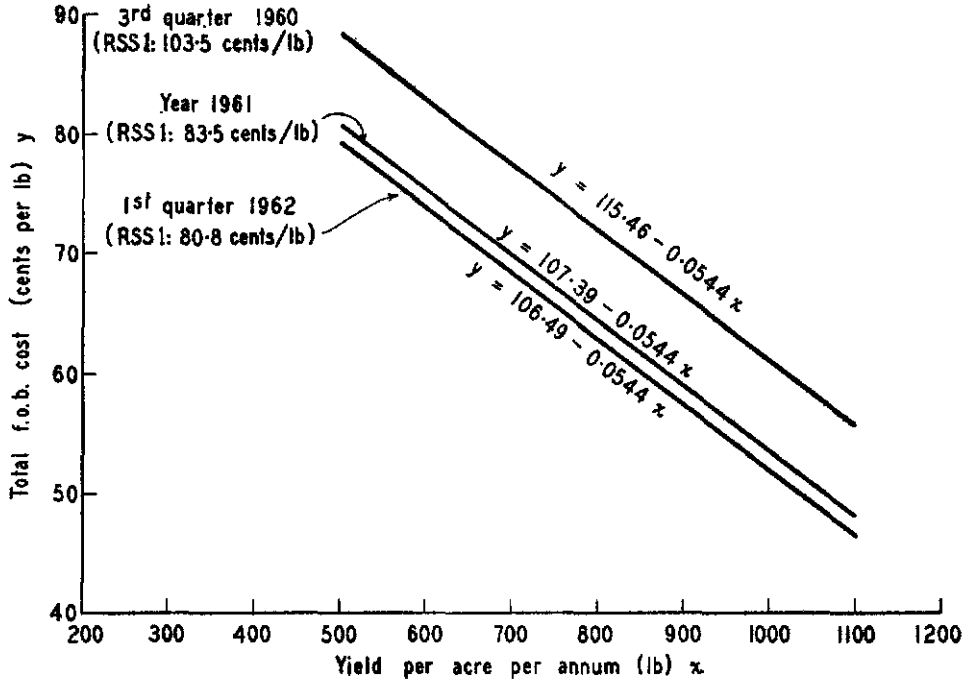

Figure 2. Relation between total f.o.b. costs (cents per lb) and yield per acre per annum (lb) using a common slope for each period.

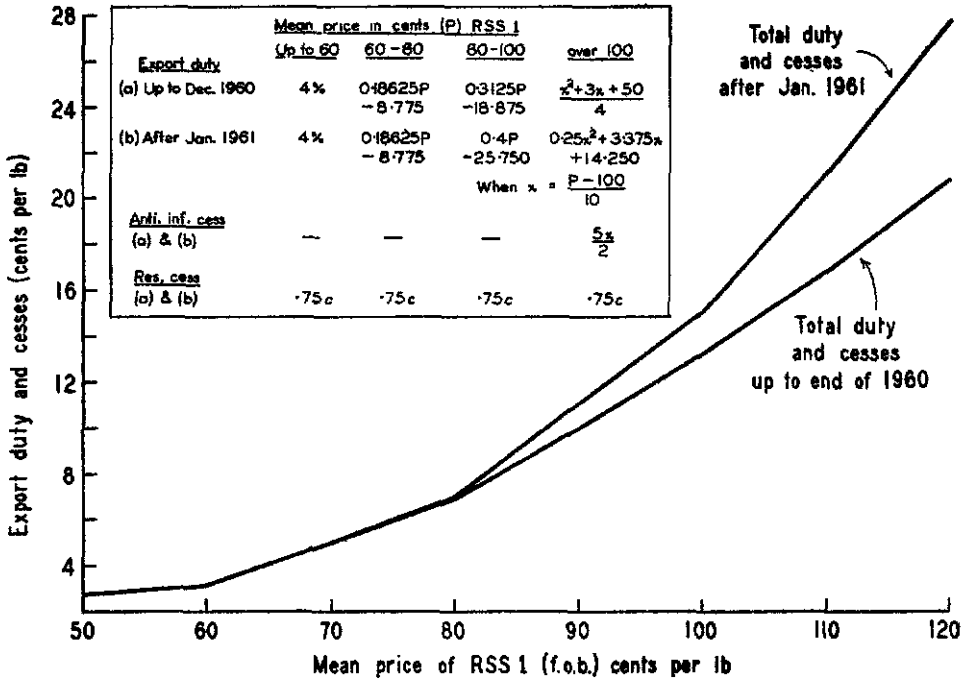

Figure 3. Relation between export duty and cesses and price of RSS 1 (f.o.b.).

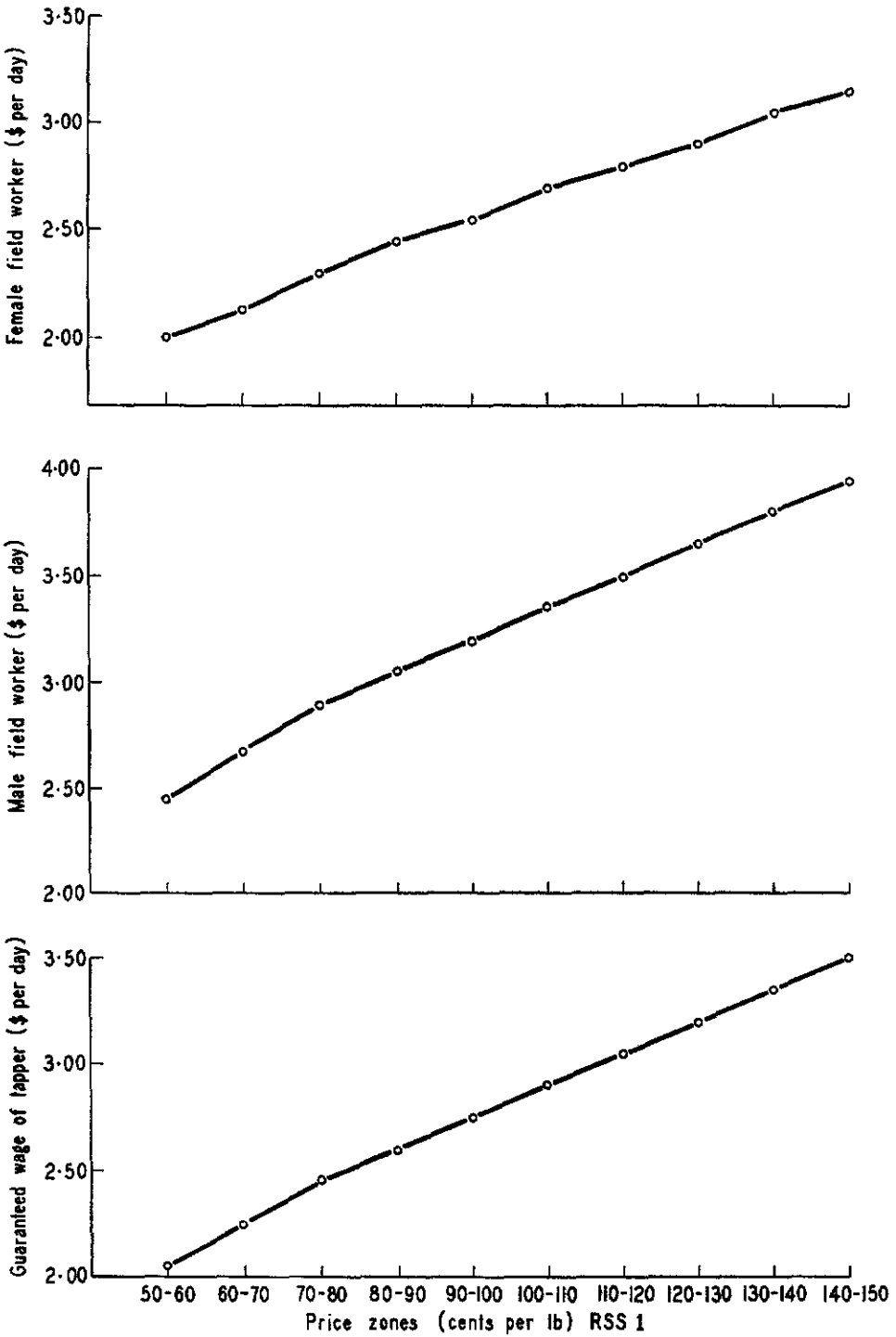

Figure 4. Relation between guaranteed daily wages of tappers or field workers and the price of RSS 1. (From M.P.I.E.A. Wage Agreement).

$$y' = 78.15 - 0.0432x$$

Assuming, at this stage, that the price effect on revenue cost is confined to tapping, collection and upkeep costs, then the revenue cost equation at 85 cts per lb can be extended to other price zones as shown in *Table 3*. These revenue cost regression lines are shown in *Figure 5*.

EXTENSION OF THE TOTAL F.O.B. COST EQUATIONS FOR A WIDE RANGE OF RSS 1 PRICES

The revenue cost equation in *Table 3* can be converted to total f.o.b. cost equations by adding, as in *Table 4*.

(i) the appropriate duty and cesses
(ii) selling charges at 3 cts per lb
(iii) depreciation, $d = 18.2 - 0.0112x$ cts per lb.

These total f.o.b. cost equations are also shown in *Figure 5* with the corresponding revenue cost equations. The validity of applying these equations beyond the range of 500-1100 lb per acre per annum is questionable.

RELATION BETWEEN AVERAGE PRICE RECEIVED AND RSS 1 PRICE

Estate sheet production does not consist solely of RSS 1. Cup lump and other scrap, amounting to about 15% of the total, may be converted to blanket crepe which brings a lower price and incurs an additional manufacturing cost of about 2 cts per lb. Price differences due to grade have varied markedly in the past and show no definite relation with the general price level. As a rough approximation it will be assumed that 15% of the production is sold at 10 cts per lb less than RSS 1 (after making provisions for additional processing costs). Thus if the RSS 1 price is p cts per lb, then the average price obtained is

$$p^1 = \frac{85}{100} p + \frac{15}{100} (p - 10)$$
$$= p - 1.5 \text{ cts per lb}$$

That is, the average price received is about $1\frac{1}{2}$ *cts per lb less than the RSS 1 price.*

THE DISTRIBUTION OF YIELDS PER ACRE

The cumulative percentages of

(a) number of companies
(b) production
(c) acreage in tapping

are each plotted against yield per acre per annum in *Figure 6* for the 115 sample companies in 1961.

Corresponding cumulative distributions for all the Malayan estates are given in *Figure 7*. (Source: *Rubber Statistics Handbook 1961*). For example, the graphs show that 57% of Malayan estates accounting for 35% of the tapped acreage and only 20% of estate production yielded less than 600 lb per acre per annum in 1961.

Using these cumulative distributions and the total f.o.b. cost equations (*Table 4*), it is possible to estimate the percentages of producers liable to operate unprofitably at various price levels, and to estimate the percentage acreage and production affected.

PERCENTAGES OF 'UNPROFITABLE' PRODUCERS AT DIFFERENT PRICE LEVELS

For a given RSS 1 price, the average price received is determined and substituted in the

TABLE 4. EQUATIONS RELATING TOTAL F.O.B. COST PER LB (y) AND YIELD PER ACRE PER ANNUM (x) AT DIFFERENT PRICES OF RSS 1

Price zone (cts/lb)	Mid - value (cts/lb)	Duty and cesses (cts/lb)	Selling charges (cts/lb)	Regression equations
50—60	55	2.95	3.00	y= 99.40-0.0544x
60—70	65	4.08	3.00	y=101.53-0.0544x
70—80	75	5.94	3.00	y=104.49-0.0544x
80—90	85	9.00	3.00	y=108.35-0.0544x
90—100	95	13.00	3.00	y=113.15-0.0544x
100—110	105	18.00	3.00	y=118.95-0.0544x

TABLE 5. PERCENTAGES OF UNPROFITABLE PRODUCERS AT DIFFERENT PRICE LEVELS OF RSS 1

A: Assuming full depreciation provision

Price, Singapore (cts per lb)	Average price received (cts per lb)	'Break-even' yield/ac/year (lb)	Unprofitable percentages					
			Sample companies			All estates		
			Companies	Production	Acreage	Estates	Production	Acreage
55	53.5	844	59	34	43	78	50	65
65	63.5	699	27	16	20	67	31	47
75	73.5	570	7	4	6	53	18	32
85	83.5	457	—	—	—	39	8	19
95	93.5	361	—	—	—	27	3	11
105	103.5	284	—	—	—	17	1	5

B: Assuming no depreciation provision

Price Singapore (cts per lb)	Average price received (cts per lb)	'Break-even' yield/acre/ year (lb)	Unprofitable percentages					
			Sample companies			All estates		
			Companies	Production	Acreage	Estates	Production	Acreage
55	53.5	641	16	10	13	61	24	39
65	63.5	459	—	—	—	40	8	19
75	73.5	296	—	—	—	19	2	6
85	83.5	154	—	—	—	5	<1	1
95	93.5	34	—	—	—	—	—	—
105	103.5	—	—	—	—	—	—	—

appropriate total f.o.b. equation. The resulting yield per acre per annum is the 'break-even' yield required, on average, to maintain a total f.o.b. cost equal to the price received. Applying the 'break-even' yield per acre to the cumulative distributions, the percentage of unprofitable companies (or estates) and their corresponding tapped acreages and production are read off. These are summarised in *Table 5A* for the sample companies and for the Malayan estate population.

It should be noted that the total f.o.b. equations used to prepare *Table 5A* include the full depreciation provision which amounts to about 14 cts per lb for a 400 lb per acre estate and 7 cts per lb for a 1000 lb per acre estate. If no depreciation provision is included in the f.o.b. costs, then the 'break-even' yields are distinctly lower. The results are summarised in *Table 5B*.

Superficially, *Table 5A* would seem to be in gross error because it implies that at a price of 75 cts per lb for RSS 1, about half of the Malayan estates (representing 18% of the estate production) are failing to make a profit. The explanation is simply that at this price these low-yielding estates are unable to sustain a depreciation charge which will fully provide for replacement and replanting. If no depreciation provision is made, then only 2% of the estate production is liable to be unprofitable at 75 cts per lb RSS 1.

THE EFFECT OF LOW PRICES

The production cost equations and the details given in *Table 5* are not intended to

represent an accurate forecast of what will happen if the price of rubber falls to a much lower level, say, below 70 cts per lb. Instead, they illustrate the recent situation in the price range 80 to 100 cts per lb, and give estimates of what would happen at lower prices provided:

(a) no additional measures to improve productivity are undertaken,

(b) the distribution of estate yields per acre remains unaltered from that of 1961.

In fact, the yield per acre distribution is steadily undergoing improvement. Averaging over the last four years, the mean yield per acre on estates has increased about 40 lb per year. Further, if the price of rubber fell heavily and continued at a low level, producers would be likely to take new measures to adapt to the new situation; and costs, yields per acre, and total estate production might then be markedly different.

Despite the limitations of the cost equations as an accurate forecast, they do provide a measure of the economies which must be made by various producers if they are to remain profitable in times of low prices. The profit (or loss) margins with different yields per acre at different prices are shown in *Figure 8 A* and *B* (with and without provision for depreciation). The graphs demonstrate that a producer yielding 1000 lb per acre can sustain a substantial fall in price, and is in a strong position in relation to present competition from synthetics. But the average producer at 500 lb per acre, when making no depreciation provision, is liable to suffer loss when the price falls below about 62 cts per lb.

BREAKDOWN OF REVENUE COSTS

We do not have detailed information on the breakdown of revenue costs for a large number of companies at times of different prices. However, an estimate of such a breakdown is shown in *Figure 9*. It is based on detailed revenue cost analysis of only 10 estates supplemented by information on percentage breakdown of costs on a further 19 estates. Yields per acre of these sample estates range from about 400 to 1100 lb per acre per annum. The average price of RSS 1 was 80 cts per lb. *Figure 9* is therefore less reliable than the aggregate revenue cost information based on much more extensive data, but it serves to illustrate the relative importance of the various items in the revenue cost at different levels of yield per acre.

For the sample estates, with a mean yield of 800 lb per acre per annum and an RSS 1 price of 80 cts per lb, the percentage breakdown of revenue costs is as follows:

Tapping and collection	46.6%
Upkeep and cultivation	12.9%
General charges	25.7%
Manufacture	10.7%
Packing and despatch	4.1%
Revenue cost	100.0%

Manufacturing costs refer only to those estates producing smoked sheet.

Figure 9 shows that increased yield per acre tends to reduce the costs per lb of upkeep and of general charges, and markedly reduces tapping costs per lb; the costs per lb of manufacture and of packing and despatch are unaffected. The equations relating the costs per lb of the separate items with the yield per acre per annum, x, are as follows:

Tapping and collection:

$$t = 41.8 - 0.027x \text{ cts per lb}$$

Upkeep and cultivation:

$$u = 9.6 - 0.005x$$

General charges:

$$g = 20.0 - 0.011x$$

Manufacture:

$$m = 4.6$$

Packing and despatch:

$$pd = 1.8$$

Total = revenue cost :

$$y' = 77.8 - 0.043x \text{ cts per lb}$$

The total corresponds to the revenue cost equation for an RSS 1 price of 80 cts per lb. The effects of price change on the separate revenue cost items have been discussed above under 'Influence of price on revenue cost per lb'. Automatic price effects operating through the wage agreement are expected to be confined to tapping and upkeep, and are not very marked. Effects of special measures introduced at times of low price may be much greater and are less readily predicted.

Low yielding estates have the highest revenue cost, and the highest costs for tapping, upkeep and general charges, when these are

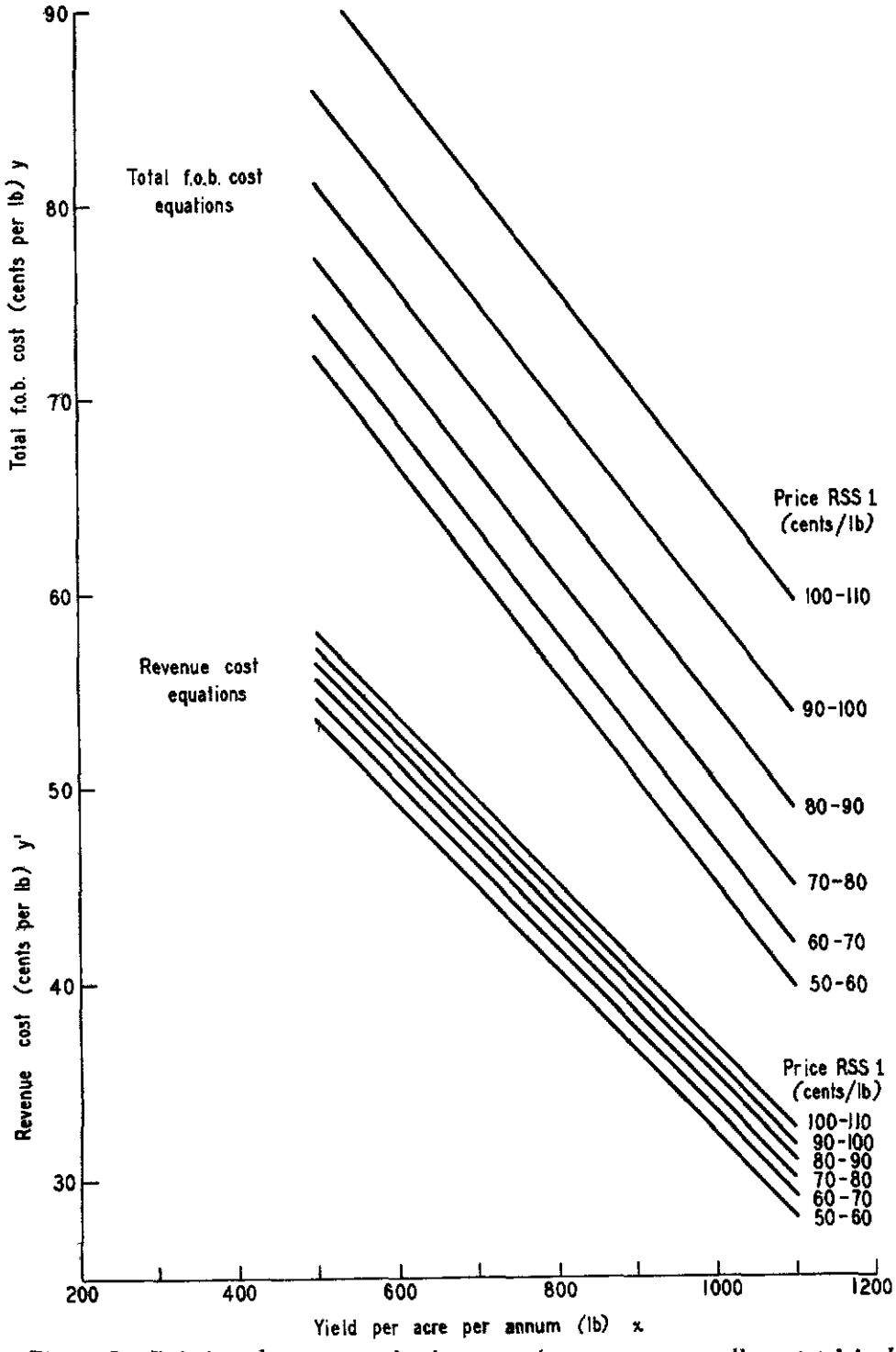

Figure 5. Relations between production costs (revenue cost per lb or total f.o.b. cost per lb) and yield per acre per annum under different price conditions.

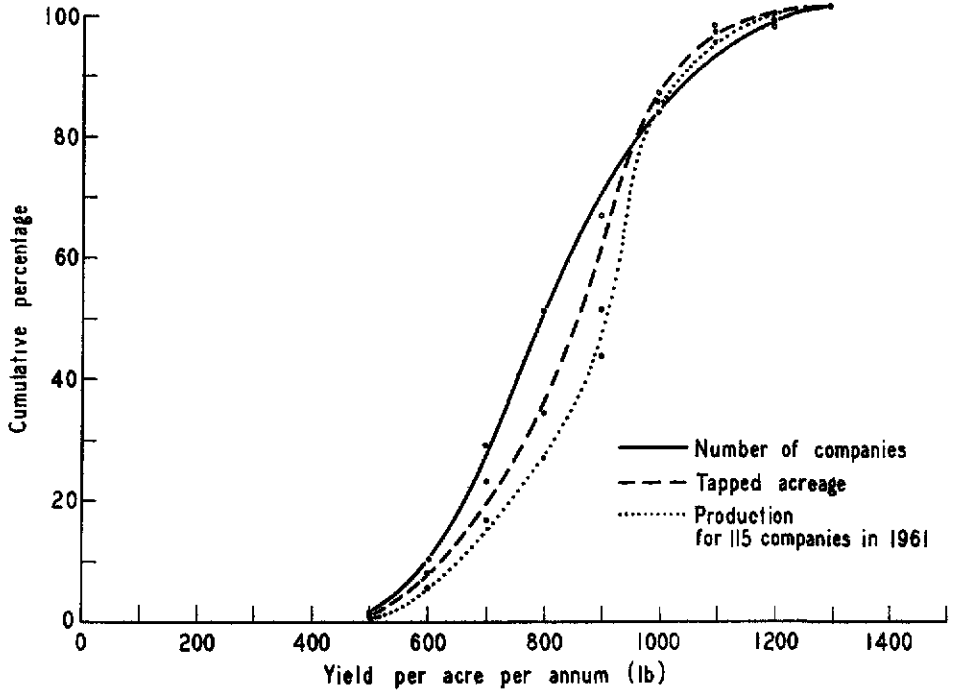

Figure 6. Cumulative percentage of number of companies, tapped acreage, and production at different yields per acre per annum.

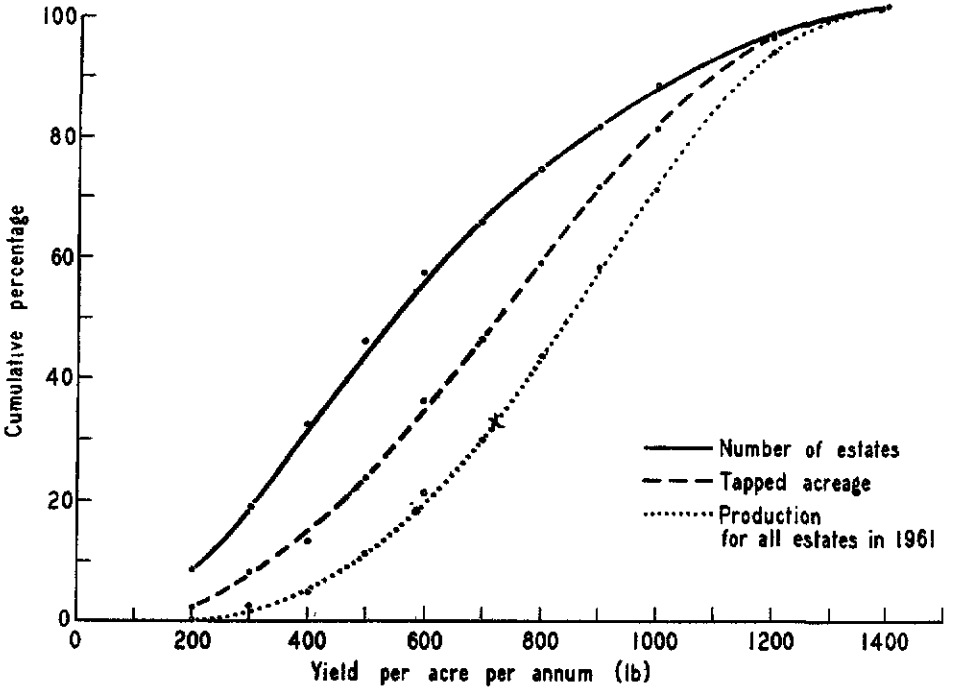

Figure 7. Cumulative percentage of Malayan estates, tapped acreage, and production at different yields per acre per annum.

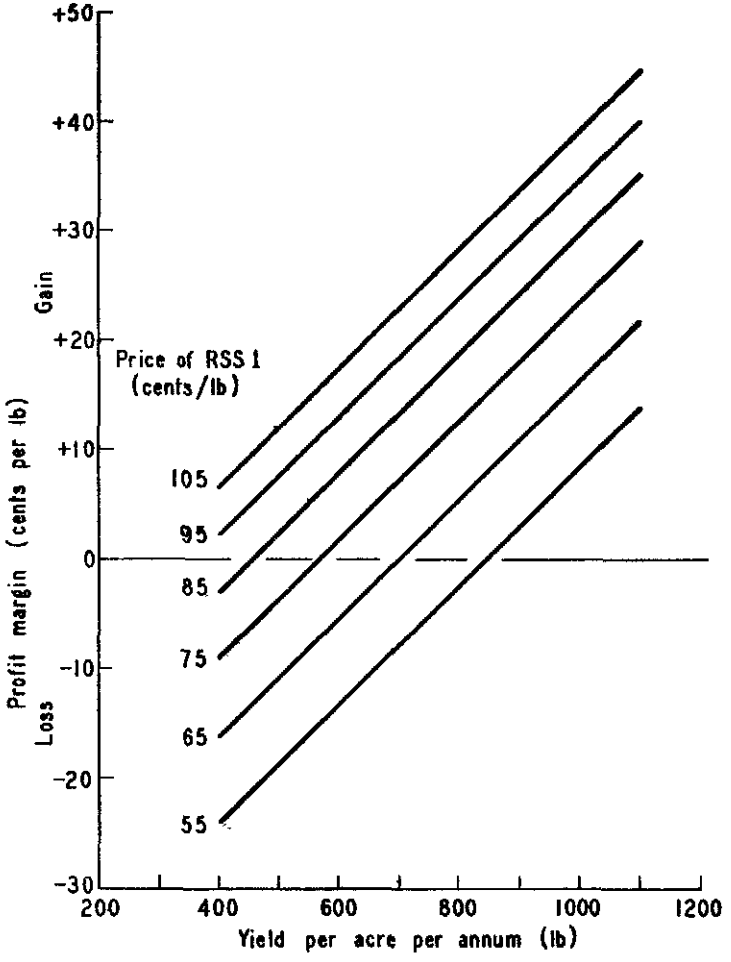

Figure 8A. Profit margin (cents per lb) at different prices and yields per acre per annum, with no provision for depreciation.

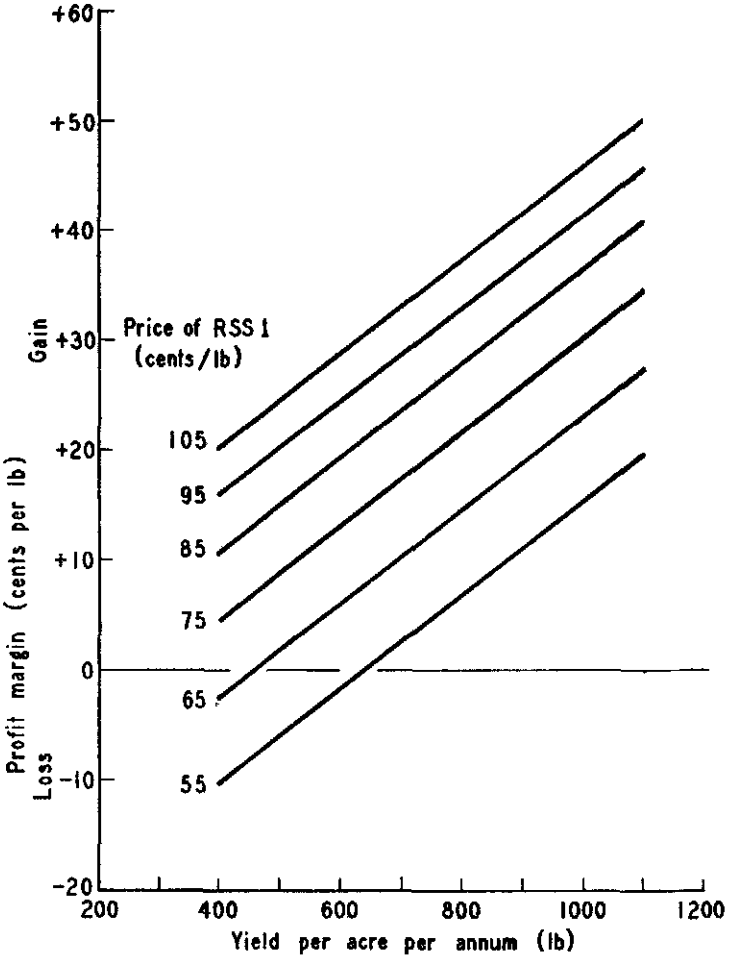

Figure 8B. Profit margin (cents per lb) at different prices and yields per acre per annum, with no provision for depreciation.

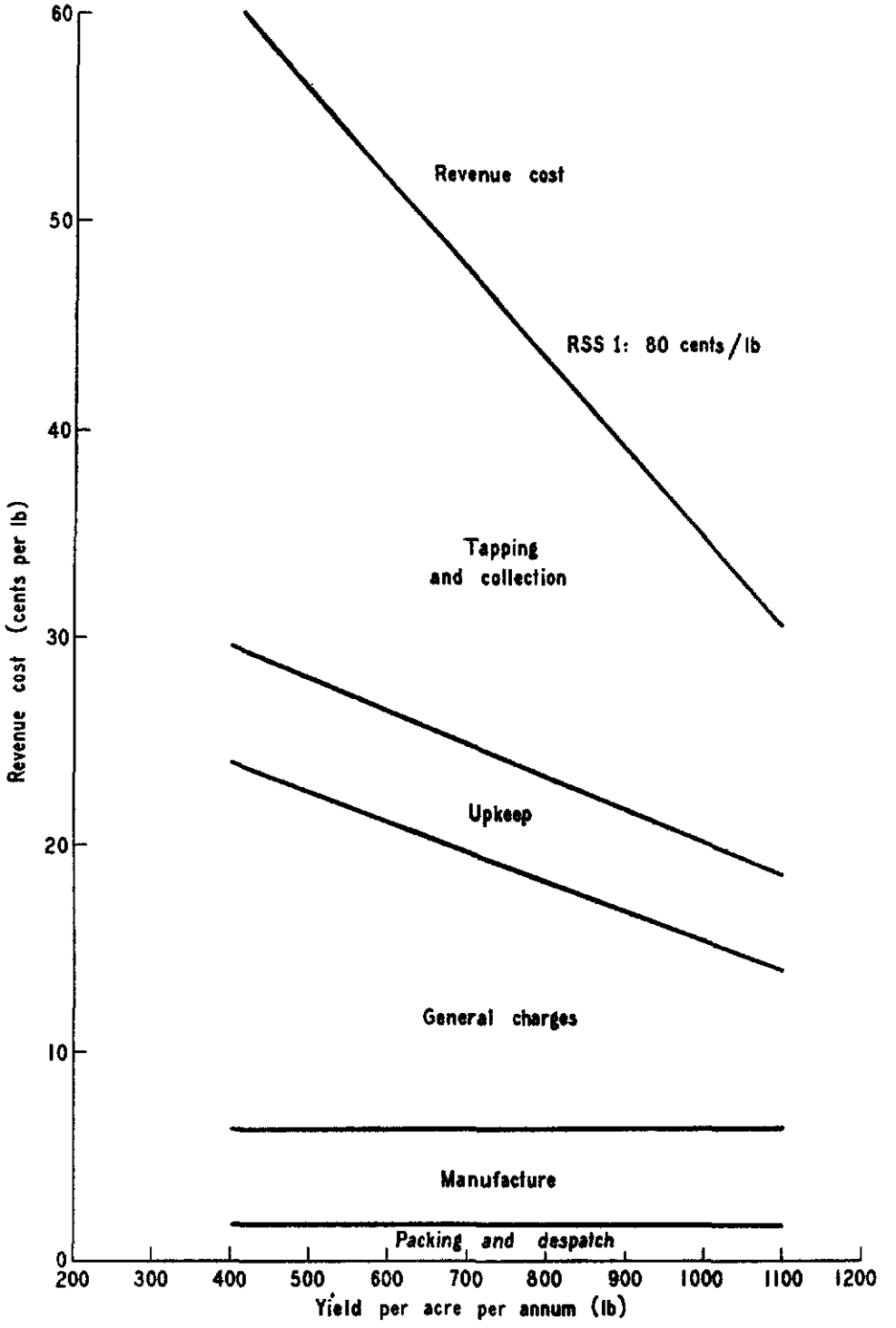

Figure 9. Breakdown of revenue costs at different yields per acre per annum.

measured in terms of costs per lb. But when these charges are expressed as costs per acre, their relationships with yield per acre (which can be readily derived from the cost per lb equations) are curvilinear; low yielding estates tend to have the lowest costs per acre, and the heaviest charges per acre occur on estates with yields in the region of 800 to 1,000 lb per acre per annum.

MEASURES WHICH MIGHT BE ADOPTED TO INCREASE PRODUCTIVITY WHEN THE PRICE IS LOW

Some of the following measures might improve productivity:

(a) Change of tapping systems.
Reduction of intensity by less frequent tapping or introducing resting periods may reduce tapping costs markedly but will also adversely affect yields. The most appropriate system is that which maximises the long-term profit per acre, and this will depend on the condition and type of planting material, the potential yield per acre, and the rubber price. With high yielding estates (or tasks) the loss in yield is less likely to offset the saving in tapping costs. The effect on the economic life of the trees and the rate of depreciation is important.

(b) Wider use of yield stimulation.

(c) Change in task size.
Increasing the task size, where possible, will clearly increase the productivity per tapper and reduce tapping costs per lb, but has some adverse effect on yield per acre due to later tapping. The advantage of the larger task is more likely to lie in low yielding tasks.

(d) Selective tapping of tasks.
The profitability of tasks varies widely according to their yield per acre. At low prices some will cease to be profitable and may remain untapped or be given extreme resting periods.

(e) Selective tapping of trees within tasks.
Another possibility is to increase task areas for variable material and tap only selected trees. The extra walking per tapped tree is unlikely to make this measure worthwhile except when the price is very low.

(f) Economies in upkeep and general charges.
Major reductions in current average expenditure on upkeep and supervision may be of doubtful value on a long-term basis.

(g) Replanting.
The various cost relationships given in this paper emphasise the obvious importance of replanting. High-yielding producers are able to withstand further severe price competition, but a substantial proportion of Malayan producers can probably only survive at prolonged low price by replanting.

ACKNOWLEDGEMENT

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Statistics Division
Rubber Research Institute of Malaya
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APPENDIX A: NOTE ON DEPRECIATION CHARGES

The equation used in this paper for the relation between depreciation cost per lb, d, and the yield per acre per annum (lb), x, is $d = 18.2 - 0.0112x$ .....(1)

The equation agrees approximately with the following notional depreciation charges.

(a) Depreciation of building, machinery and transport.

Assume a fixed value of \$400 per acre depreciated at 7½% p.a.

Then charge per lb,

$$d_1 = 400 \times \frac{7.5}{100} \times \frac{100}{x}$$

$$= \frac{3000}{x} \text{ cts per lb}$$

(b) Depreciation of trees.

Assume a replanting cost of \$1000 per acre depreciated at 4% p.a.

Then charge per lb,

$$d_2 = 1000 \times \frac{4}{100} \times \frac{100}{x}$$

$$= \frac{4000}{x} \text{ cts per lb}$$

The sum of these two charges is

$$d' = d_1 + d_2 = \frac{7000}{x} \text{ cts per lb} \quad .....(2)$$

Equation (2) is curvilinear, and for convenience the linear approximation given by equation (1) has been adopted. The agreement is satisfactory in the yield range 500 to 1100 lb per acre per annum:

Yield per acre per annum:	x = 500	700	900	1100 lb
Depreciation, equation (1):	d = 12.6	10.4	8.1	5.9 cts per lb
Depreciation, equation (2):	d' = 14.0	10.0	7.8	6.4 cts per lb

APPENDIX B: EXAMPLE OF THE EFFECT OF PRICE CHANGE ON TAPPING AND UPKEEP COSTS

It has been estimated that, on average, a fall of 10 cts per lb in the price of RSS 1 reduces joint tapping and upkeep costs by about 0.8 cts per lb. This may be illustrated by the following example:

Suppose an estate has a mean yield of 800 lb per acre per annum. Let the average task size be $3\frac{1}{2}$ acres, and let half the tappers operate system S/2.d/2.100% and the remainder operate S/2.d/3.67%. Then the average acreage operated per tapper is:

$$= \tfrac{1}{2}\{(2 \times 3\tfrac{1}{2}) + (3 \times 3\tfrac{1}{2})\}$$

$$= 8.75 \text{ acre}$$

Hence the mean production per tapper per annum is:

$$8.75 \times 800$$
$$= 7{,}000 \text{ lb}$$

Suppose the RSS 1 price falls 20 cts per lb from zone 100 – 110 cents to zone 80 – 90 cents. The corresponding fall in a tapper's guaranteed daily wage is 30 cents. For a year of 315 tapping days, this represents a reduction of \$94.50 in a tapper's annual earnings. There are approximately four tappers to each field worker, and the fall in a field worker's daily wage is similar to that of a tapper.

Hence, the total annual reduction in tapping and upkeep costs for each 7000 lb production is: $\frac{5}{4} \times 94.50 = \$118$.

The reduction in tapping and upkeep cost per lb is:

$$\frac{118}{7000} \times 100 \text{ cts}$$
$$= 1.7 \text{ cts}$$

That is, a fall of 10 cts per lb in the price of RSS 1 causes a fall of 15 cts per day in a tapper's wages and about 0.8 cts per lb in revenue cost.